DRAG ON CONICAL PARTICLES IN NEWTONIAN AND POWER LAW FLUIDS

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MASTER OF TECHNOLOGY

By

APARAJITA BORAH

DEPARTMENT OF CHEMICAL ENGINEERING

INDIAN INSTITUTE OF TECHNOLOGY KANPUR

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CERTIFICATE

This is to certify that the present research work entitled "DRAG ON CONICAL PARTICLES IN NEWTONIAN AND POWER LAW FLUIDS" has been carried out by Ms.Aparajita Borah under my supervision and that this has not been submitted elsewhere for a degree.

(Dr. R. P. CHHABRA)
Professor,
Department of Chemical Engineering,
Indian Institute of Technology,
Kanpur 208016

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Aparajita Borah

DEDICATED TO MY PARENTS.

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ABSTRACT

The dependence of drag coefficient on the Reynolds number for freely falling cones, both in Newtonian and power law fluids is investigated experimentally. The effect of apex angle and orientation on the free settling behavior of cones is also studied. Several cones, encompassing wide ranges of diameter to height ratio, 0.36 to 2.7, and of cone angles, 22 to 105, have been used in this work. Terminal velocity of these cones was measured as a function of the physical properties of a series of test liquids. Furthermore, the retardation effect exerted by the confining walls on the free settling velocity has been quantified by performing experimental measurements in different size fall tubes.

Extensive experiments are carried out with spheres to establish the reliability of the experimental technique and also to calibrate for experimental uncertainty. The raw experimental data on terminal velocity is converted to more useful dimensionless variables. Based on the large body of data for Newtonian as well as non-Newtonian fluids, it is demonstrated that the use of an equivalent volume sphere diameter gives an adequate method of characterizing the free settling behavior of non-spherical particles. Based on this notion, an appropriate unified correlation has been developed for drag coefficient. The ratio of fall velocity of a falling cone to that of a spherical particle with the same equivalent diameter is presented as a function of shape factors of the cone. The dependence of the fall velocity due to confining walls is studied as a function of the diameter ratio between the base diameter of the cones and the diameter of the tubes and also the Reynolds number of the cones. Also, the present results have been contrasted with the prior pertinent experimental and theoretical studies available in the literature. The present investigation encompasses the following ranges of conditions,

Newtonian Fluids

$19 \times 10^{-4} \leq Re_{\infty} \leq 507$; $0.0498 \leq (d/D) \leq 0.234$; $0.02 Pa.s \leq \mu \leq 12.2 Pa.s$;

Non-Newtonian Fluid

$0.021 \leq Re'_{\infty} \leq 140$; $0.0498 \leq (d/D) \leq 0.264$; $0.403 \leq n \leq 0.72$;

Chapter 1

INTRODUCTION

Non-Newtonian fluid behavior is encountered in an overwhelming number of situations throughout the nature and in commercial operations. Typical examples of materials exhibiting non-Newtonian flow characteristics include multiphase mixtures (slurries, emulsions and gas liquid dispersions), polymer melts and solutions, biological fluids (blood, synovial fluid, saliva, semen etc.) and agricultural and dairy waste etc. Other examples of importance include the enhanced recovery of oil from oil shale, industrial waste flows, process slurry operations, polymer and plastic synthesis and fabrication, food processing and in biological processing, etc. Due to such widespread applications, considerable work has been devoted towards the understanding of the flow behavior of non-Newtonian fluids in a range of hydrodynamic situations. One important class of problems involves the motion particles in quiescent non-Newtonian media. This dissertation is concerned with this subject.

A reliable knowledge of the terminal settling velocity of particles in quiescent fluids, and of the drag force on the particles placed in moving fluid stream is often required in wide ranging applications in chemical, mineral and process industries. Typical examples include process design calculations for continuous processing of large food particles, fixed and fluidized bed reactors, pneumatic and hydraulic conveying of coarse particles, liquid solid separation and classification techniques, etc. The flow of fluid, past a particle represents an idealization of many industrially important processes. Typical examples include processing of fiber suspensions, sedimentation, fluidization and hydraulic transport of suspensions of fiber like particles, catalytic reactors employing catalyst in the form of non-spherical pellets, etc. In all these applications, the quantity of central interest is the free fall velocity of a particle falling under gravity, which is strongly influenced by the shape and orientation of the particle, the presence of finite boundaries and the rheological properties of fluids.

While considerable attention has been given to the hydrodynamic behavior of the single spherical and non-spherical particle in incompressible Newtonian media, the analogous problem involving non-Newtonian systems has received much less attention. A cursory examination of the authoritative reviews available on the subject reveals that most prior studies have been dealt with the motion of spherical particles and the non-spherical objects have attracted even less research work. The present dissertation aims to bridge this gap in the currently available body of information on this subject.

In particular, the objectives of this work are to report on the drag coefficient of conical shaped particles in a variety of Newtonian and non-Newtonian systems and to ascertain the influence of wall effects on drag. On the basis of experimental results, correlation to find the ratio of terminal settling velocity of non-spherical to that of spherical particles are reported. Empirical correlation is also reported for the drag coefficient of non-spherical conical particles in both Newtonian and non-Newtonian media. The dependence of wall effect on the diameter ratio (ratio of diameter of the particle to that of the tube) and the terminal Reynolds number of the falling particle is also studied.

Chapter 2

LITERATURE SURVEY

In this chapter, a brief account of the prior studies on the free settling behavior of regular but non-spherical shaped particles like cylinders, regular prisms, needles and cones, etc. in Newtonian and non-Newtonian fluids is presented which in turn facilitates in identifying the objectives of this work. It is however useful to include a brief account on the free settling behavior of spherical particles.

2.1 NEWTONIAN MEDIA

2.1.1 Drag on a Sphere

Considerable amount of work has been reported on all aspects of sphere motion in incompressible Newtonian media and consequently, a wealth of information is also available on the macroscopic as well as microscopic fluid flow phenomena in this flow configuration. Stokes [1] results are valid only in the slow flow limit ($Re \rightarrow 0$ i.e. Stokes flow) in an unconfined fluid. Oseen [2] provided a better approximation for unconfined flow but for finite Reynolds number. However, most of the developments in this area up to 1978 are summarized in the classic book of Clift *et al.* [3]. Other sources of information include Happel and Brenner [4] and Hetsroni [5]. Magarvey and Bishop [6] used dye visualization method to reveal the wakes of freely falling drops of an immiscible liquid in water, which can be qualitatively compared with flow past solid sphere, due to the presence of surface active impurities at the liquid-liquid interface which held the liquid in a semi rigid spherical shape as pointed out by Natarajan and Acrivos[7]. The wakes of liquid spheres exhibited vortex ring which remain stable and axisymmetric up to Re=210.

Several numerical methods are also employed to calculate the drag coefficient for flow around a sphere. Some of such works are Tomboulides [8], Natarajan and Acrivos [7], Johnson

and Patel [9] etc. Johnson and Patel however used experimental methods also to validate their numerical results.

2.1.2 Drag on Non-Spherical Particles:

Analogous studies involving non-spherical particles have been less extensive and the resulting literature is also not as cohesive as that in the case of spherical particles. The scant literature available on this topic has also been summarized by Clift *et al.* [3] and subsequently by Kim and Karrila [10]. But a terse account of the pertinent studies in included here, however.

Theoretical treatments have generally been limited to the creeping motion of axisymmetric bodies such as oblate, prolate, spheroids, disks or slender bodies such as needles. Analytical expressions for the relevant stream function and drag coefficient are available in the literature [3]-[4], [10]. Limited results for the settling of spheroids outside the creeping flow regimes are also available e.g. see Masliyah and Epstein [11]. However, no analogous analysis for more practical shapes such as finite sized cylinders, rectangular prisms, cones, etc. is available, except a few for the case of cylinders.

It is readily recognized that the drag force experienced by an object settling in a quiescent viscous medium is strongly influenced by the shape and orientation of the body apart from the usual variables such as its size, density and the density and viscosity of the fluid. For instance, depending upon the values of the Reynolds number and on the length to diameter ratio, a cylinder may settle with its axis normal or parallel to the direction of motion. A satisfactory mathematical description of particle shape for the non-spherical particles is not yet available and is one of the most impediments in developing universal "drag curves", akin to the standard drag curve for sphere motion in Newtonian media. Currently, there are two approaches available to represent and correlate the terminal settling data for non-spherical objects. In the first approach the usual drag coefficient –Reynolds number form is used. The works of Finn [12], Jones and Knudsen [13], List and Schmenauer [14], Kasper *et al.*[15], Unnikrishnan and Chhabra [16], Sharma and Chhabra [17], Venu Madhav and Chhabra [18], Chhabra *et al.*[19] etc. illustrate the applicability of this approach. Much confusion, however, exists regarding the choice of a suitable linear dimension. Some investigators have found the use of a volume equivalent sphere diameter (d_{eq}) satisfactory ([17, 18, 20, 21]. Some others have advocated the use of a shape factor together with an equivalent volume sphere diameter [22-24]. Yet, some others have employed an equivalent diameter based on the specific surface

area and/or sphere diameter based on equal surface areas, etc. Kasper [25] has written an interesting article on the relative merits and demerits of a variety of equivalent diameters and shape factors currently used in correlating the drag coefficient data. Irrespective of the choice of a suitable equivalent diameter (whether in conjunction with a shape factor or not), this approach endeavors to reconcile drag coefficient data for variously shaped particles into one curve, akin to standard drag curve for spheres. Sometimes, additional geometric factors such as length to diameter ratio in case of cylinders also appear in the final drag expressions e.g. Cho *et al.* [26]. Chhabra *et al.* [27] evaluated most of the widely used correlations to find the drag coefficient of non-spherical particles and also compared them with experimental data from 19 independent studies embracing wide range of particle shape and sphericity, ψ.

In the other approach, the terminal velocity measurements are represented and correlated in terms of a velocity ratio. In essence, this approach denotes the behavior of a non-spherical particle in comparison with that of an equivalent sphere diameter of the same volume and some other geometric ratios. This approach introduces a sphericity factor, ψ, which is defined as the ratio of the surface area of a sphere (of the same volume) to that of the actual particle. Another linear dimension, d_n, is introduced which is defined as the diameter of a circle having same area as the projected area of the particle in the direction normal to that of the flow. Finally one defines a factor, K', which is the ratio of the settling velocity of a non-spherical particle to that of a sphere of the same volume equivalent diameter. This approach has been used, for instance by [17-24] and also by Singh and Roychoudhury [28]. Though, this approach has proved to be successful for correlating the experimental results for variously shaped particles, a universal correlation encompassing all shapes of interest under wide conditions in yet to emerge.

Lately, some numerical methods have been also employed to study the flow around non-spherical objects in Newtonian media at different ranges of Reynolds number. A few of them are as follows, Munshi *et al.* [29], flow around a disk at moderate Reynolds number, Tripathi and Chhabra[30] around a spheroid, etc.

In addition to drag, much interest has also been shown in studying the effects of the confining walls, the most common being cylindrical tubes. In order to deduce the net hydrodynamic drag, one needs to apply a correction due to walls. This is also done in the present work where a short treatment of wall effects is presented here.

2.1.3 Wall Effect on a Spherical Particle:

It is well known that the presence of walls or finite boundaries exerts a retarding effect on the steady terminal velocity of particles in a viscous medium. A reliable knowledge of the so called wall effect is required to deduce the net hydrodynamic drag on the particle solely due to the relative motion between the particle and the fluid media. Depending upon the aspect ratio, λ (ratio of diameter of the spherical particle to that of the fall tube), the confining walls, exert additional retardation force on the moving body. It is customary to introduce a wall factor, f_w, which is defined as the ratio of the measured terminal velocity in a bounded medium to that in the unbounded medium. Thus, the value of wall factor ranges from 0 to 1. A voluminous body of knowledge is available on the wall effects of sphere motion in cylindrical and non-circular geometries in low Reynolds number [3], [31] etc. It is generally agreed that the wall factor is independent of Reynolds number at low and very high values, while in between both these limits, the wall correction factor is a function of both Re and λ. So it is customary to identify three flow regimes for friction in pipe flow namely viscous, transition and inertial/fully turbulent regions. Wall effects at high Reynolds number have been thoroughly studied by different authors. Chhabra *et al.*[32] reviewed the experimental results by different authors and had proposed correlations relating λ and Re to f_w at different regimes.

2.1.4 Wall Effects on Non-Spherical Particles:

Much less is known on the extent of wall effects on the free settling motion of non-spherical objects. Some investigators have ignored the wall effect while others have applied the same correction as that for spheres ([22], [33]-[36]). Clearly, neither of these practices is justifiable. Kasper [15] has clearly shown the importance of wall effects on the creeping motion of arbitrary shaped particles as that for spheres. For instance, the aspect ratio, λ (sphere/cylinder diameter) of 0.1 causes 21% reduction in the free settling velocity of a sphere in the creeping flow regime. This uncertainty coupled with the confusion concerning a satisfactory definition of the non-spherical particle shape has indeed hampered the development of a unified correlation for non-spherical particles settling in incompressible Newtonian media.

2.2 NON-NEWTONIAN FLUIDS

2.2.1 Drag on Spherical particles:

Over the past few decades, a considerable amount of work has been carried out on the steady flow of generalized Newtonian fluids around a sphere. From the theoretical standpoint, it is readily acknowledged that the pertinent field equations describing the steady, incompressible viscous flow around a sphere are highly non-linear due to complex rheological behavior of the fluid, even when the non-linear inertial terms are neglected altogether in non-Newtonian fluid. This complexity alone preludes the possibility of rigorous analytical solutions, even for the simplest non-Newtonian viscosity model, namely the power law. Analytical results are available using variational method, by Wasserman and Slattery [39], Cho and Hartnett [40], Kawase and Moo-Young [41] for creeping flow over an unconfined sphere.

Numerical method is also used by various authors for studying the flow around a sphere in low Reynolds number. Lockyer *et al.* [42], Crochet *et al.*[43], Dazhi and Tenner[44] studied the flow around a sphere in power law fluid in the creeping flow regime. Bush and Phan-Thien[45] and Zheng *et al.*[46] solved the problem for Carreau model. Tripathi and Chhabra [30] solved for flow around a spheroid in shear thickening (dilatant) fluid at moderate Reynolds number. For the same range of Re, the flow around a spheroid is also solved for power law shear thinning fluid by Tripathi *et al.* [47].

As reviewed by Owens and Phillips [48], all the experimental studies related to flow of non-Newtonian fluids past a sphere are mainly concerned with the low Reynolds number range. Extensive literature relating to the behavior of sphere has been critically reviewed by Chhabra [37].Graham and Jones [49] carried out a numerical study for power law liquids ($n=0.4-1$) flowing past a sphere in a tube for Reynolds number (based on sphere radius) range 0.2 to 100 for two blockage ratios 1/30 and 1/50 which resembles the unbounded flow around a sphere. Most recently Ahmed [50] studied the flow around a spherical particle in Newtonian and shear thinning ($n=0.4-1$) fluids in the Reynolds number range 0.1-100.

2.2.2 Drag on Non-spherical Particles:

In contrast, the contemporary literature on the free settling motion of non-spherical particles in non-Newtonian media is indeed very limited; most of it has been summarized by Chhabra[37]. One configuration which has received considerable attention is the cross flow of

viscoelastic fluids over infinitely long cylinders but rarely expressions/computed results for drag have been reported. The streamline pattern has been the main subject of enquiry [37], while the scant literature on non-spherical objects is tersely reviewed here. Brookes and Whitmore [51, 52] measured the drag force on cylinders, discs, ellipsoids and the prisms in Bingham plastic fluids. Some additional results for discs have also been presented by Pazwash and Robertson [53, 54]. However owing to the unrealistic values of the yield stress used by these investigators, the reliability of their correlation is uncertain .The free settling motion of slender bodies (thin wires and rods) in power law media has been studied both theoretically as well as experimentally (Manero *et al.*[55] Chiba *et al.*[56] and subsequently by Unnikrishnan and Chhabra [16], and Chhabra *et al.*[19]. This configuration has also received some impetus from the potential of falling needle or cylinder viscometry. Apart from these investigations, scant data on the parallel motion of cylinders, cones and irregular shaped gravel particles in power law media have respectively been reported by Unnikrishnan and Chhabra [17], Sharma and Chhabra [18] and Subrahmanyam and Chhabra [57]. Rodrigue *et al.*[58] studied the various experimental results for non-spherical particles such as cylinders, square bars, crushed rocks etc. in power law and Carreau viscosity model fluids and presented the drag coefficient as a function of Reynolds number and Deborah number.

Corresponding but meager data on marble chips and discs are also available in the literature (Reynolds and Jones [59]). It is somewhat surprising that in none of these studies, attempt has been made at developing unified correlations.

2.2.3 Wall effects on Spherical Particles:

Chhabra [38] based on an extensive experimental study proposed the empirical correlation for the wall factor in the range of conditions $0.5 \leq n \leq 1$; $0.01 \leq Re'_m \leq 1000$ and diameter ration $\lambda \leq 0.5$.The wall effect in visco elastic fluid is studied by Chhabra [37].

2.2.4 Wall Effects on Non-Spherical particles:

It is also worthwhile to mention here that excepting the limited results on wall effects on cylinders, cones, plates and disks sedimenting in power law fluids [16-19], no information is available on wall effects in these systems .This work aims to fill the aforementioned gaps existing in the currently available body of knowledge.

2.3 OBJECTIVES

In particular, this work sets out to glean experimental data on the drag and wall effects for cones objects in free motion in incompressible Newtonian and power law type fluids. Based on the new as well as previously available data, new unified correlations for the aforementioned macroscopic parameters namely, drag coefficient and wall factor are developed and tested against the independent data available in the literature.

Chapter 3

EXPERIMENTAL MATERIALS AND PROCEDURE AND DATA ANALYSIS

In this chapter, a brief discussion of the experimental materials used, the procedure and the data analysis methods are presented. In particular, consideration is given to the description of test particles, vessel geometries and the scores of Newtonian and non-Newtonian test fluids used in this study.

3.1 MATERIALS

3.1.1 Test Liquids

The test fluids used included a wide range of Newtonian and non-Newtonian solutions as listed in table 3.1. Castor oil, silicone oil, glycerol and glucose solutions were used as Newtonian liquids. The aqueous solutions of different concentration of a high molecular weight grade Carboxyl Methyl Cellulose (Made by Loba Chemie Pvt. Ltd., Bombay) and Methocel (LR Grade) were used as model non-Newtonian fluids. The CMC and Methocel solutions exhibited purely viscous shear thinning behavior that can be well described by the usual two parameter "power law" fluid model in the range of shear rate of interest, i.e.

$$\tau = k(\gamma)^n \tag{3.1}$$

All solutions were prepared using tap water as the solvent. To ensure homogeneity, the solutions were mixed continuously over a period of 2 to 3 hours using a turbine agitator. To avoid gel formation, the solute was added in small amounts during the entire period of mixing. To prevent degradation by bacterial attack, 20 ml of 37-41%(w/v) formalin solution was added per 5 liter of the polymer solutions. Density of each test fluid was measured using a constant volume density bottle. Bohlin Rheometer was used to measure viscosity for Newtonian fluid and shear stress –shear rate behavior of non-Newtonian solutions at the same temperature as that encountered in the settling experiment .The average shear stress in the direction of

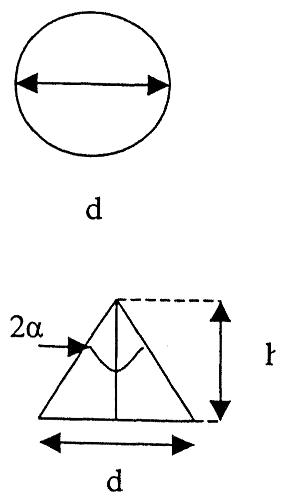
increasing and decreasing shear rates, were plotted against shear rate and from the plot the two power law constants, namely n and k were determined. The shear stress –shear rate data are taken both before and after the experiment and found to be virtually indistinguishable from each other, thereby suggesting that no degradation had taken place during the course of experiment Table 3.1 summarizes the physical properties of the test liquids used in this work.

Table 3.1 Properties of Test Fluids

Fluid	Temp(K)	Density(kg/m^3)	n	k($Pa.s^n$)
Silicon oil	308	975	1	0.260
Castor oil	308	955	1	0.473
Glycerol solution (95%)	300	1225	1	0.309
Glucose solution (95%)	302	1489	1	12.2
Glucose solution (90%)	298	1359	1	4.5
Glucose solution (85%)	298	1349	1	1.6
Glucose solution (80%)	299	1318	1	0.41
Glucose solution (75%)	299	1310	1	0.302
Glucose solution (70%)	299	1296	1	0.15
Glucose solution (65%)	298	1250	1	0.045
Glucose solution (60%)	298	1219	1	0.02
CMC solution (1.5%)	300	1000	0.403	6.883
CMC solution (1.3%)	300	1000	0.497	2.165
CMC solution (0.75%)	291	1000	0.591	0.529
CMC solution (0.6%)	291	1000	0.623	0.292
CMC solution (0.5%)	292	1000	0.616	0.261
CMC solution (0.4%)	293	1000	0.67	0.23
Methocel solution (1.2%)	296	1000	0.698	2.069
Methocel solution (1.0%)	296	1000	0.719	1.074
Methocel solution (0.75%)	288	1000	0.662	1.002
Methocel solution (0.65%)	289	1000	0.688	0.661
Methocel solution (0.5%)	289	1000	0.690	0.383

3.1.2 Test Particles

Several spherical and conical particles have been used in this work. In order to cover wide ranges of conditions, cones made up of different materials, namely Perspex, Teflon, Brass and Aluminum with different diameter and apex angle were used. These particles are characterized by a volume equivalent diameter (d_{eq}), which is defined as the diameter of a sphere with the same volume as that of the particle. For the experiments on spherical particles, spheres made up of steel, teflon and glass were used with different diameters. The geometric dimensions of the particles were measured using a micrometer or vernier calipers (least count 0.001 mm) while the density of each particle was measured by combining the weight and volume, calculated from the length and diameter. In all, 34 cones encompassing diameter to height (d/h) ratio 0.36 to 2.7 and apex angle 22 to 105, and 14 spheres in the diameter range, 6mm to 29 mm, were used in this study. The values of geometric dimension of these particles are given Table 3.2 which is obtained after taking an average of several repeated determinations in order to minimize experimental uncertainty.



Sphere
Diameter, $d=d_n=d_{eq}$
Volume, $V=\pi d^3/6$

Cone
Diameter $d=d_n$
Volume $V=\pi h d^2/12$
Volume equivalent diameter $d_{eq}=(d^2h/2)^{1/3}$
Apex angle 2α, $\alpha=\tan^{-1}(d/2h)$

Fig. 3.1 Schematics of the test particles used in the experiment with their dimensions

Table3.2: Dimensions of the Test Particles.

i) CONES

Particle ID	Length, h(mm)	Dia, d(mm)	Weight(g)	d/h	Equiv Dia (mm)	Apex angle,2α(°)	Sphericity, Ψ
Perspex	Density=	1190kg/m^3					
P1	25	15.2	1.72	0.61	14.24	33.77	0.791
P4	34.16	14.72	2.46	0.43	15.47	24.28	0.768
P7	20.4	15	1.48	0.74	13.19	40.32	0.793
P10	19.9	14.85	1.43	0.75	12.99	40.87	0.793
P13	14.95	15	1.09	1	11.89	53.21	0.778
P16	10	15	0.73	1.5	10.4	73.64	0.721
P19	5.6	14.8	0.41	2.64	8.5	105.62	0.585
P22	25	10	0.82	0.4	10.77	22.59	0.761
P25	19.7	10	0.66	0.51	9.95	28.44	0.782
P28	15	10	0.49	0.67	9.09	36.82	0.794
P31	9.86	10	0.33	1.01	7.9	53.7	0.777
P34	5.5	10	0.18	1.82	6.5	84.43	0.679
Nylon	Density=	1440kg/m^3					
N1	25.3	15	2.15	0.59	14.17	32.98	0.790
N4	19.86	10	0.78	0.5	9.98	28.22	0.782
Brass	Density=	8961kg/m^3					
B1	15.24	5.9	1.23	0.39	6.43	21.88	0.758
B4	12.2	6	1.03	0.49	6.03	27.59	0.778
B7	12	4.7	0.62	0.39	5.1	22.13	0.759
B10	8.28	6	0.65	0.72	5.3	39.78	0.793
B13	5.4	6	0.42	1.11	4.6	58.03	0.768
B16	9.9	4.72	0.53	0.48	4.8	26.78	0.778
B19	7.9	4.72	0.43	0.6	4.45	33.22	0.791
Aluminium	Density=	2700kg/m^3					
A1	11.4	9.5	0.72	0.83	8.01	45.18	0.789
A4	9.5	9.5	0.56	1	7.54	53.06	0.778
A7	8	7	0.26	0.88	5.81	47.19	0.788
A10	7	7	0.18	1	5.56	53.06	0.779
A13	5	9.5	0.26	1.9	6.09	86.94	0.671
A16	4.3	8	0.12	1.86	5.16	85.74	0.674

A19	23	9.5	1.52	0.41	10.12	23.3	0.763
A22	18	9.5	1.16	0.53	9.33	29.52	0.784
A25	14	9.5	0.92	0.68	8.58	37.43	0.793
A28	16.7	7	0.52	0.42	7.42	23.64	0.764
A31	13.6	7	0.43	0.51	6.93	28.82	0.782
A34	10.4	7	0.32	0.67	6.34	37.15	0.793

ii) SPHERE

Particle ID	Diameter, d (mm)	Weight(g)
Teflon	Density=2186kg/m^3	
T6	6	0.25
T8	8	0.58
T10	10	1.14
Steel	Density=8800 kg/m^3	
S6	5.95	1.15
S8	7.9	2.13
S10	10.38	3.63
S12	12.65	8.46
S14	13.95	10.14
Glass	Density=2765kg/m^3	
G_B	29.5	33.46
G_DB	24.5	19.6
G_GB	20.7	10.73
G_G	18.5	9.5
G_S	14.48	5.6
G_VS	12.3	3.04

3.1.2 Fall Tubes

To ascertain the significance of wall effects, terminal velocity of each particle was measured in five different fall tubes of different diameter. Dimension of the fall tubes are given in table 3.3.The length of the fall tubes varied from 1 to 1.2 m, but none was shorter than 1m,

This distance is believed to be sufficient for the particle to achieve their terminal velocity, as well as for the end effects to be negligible.

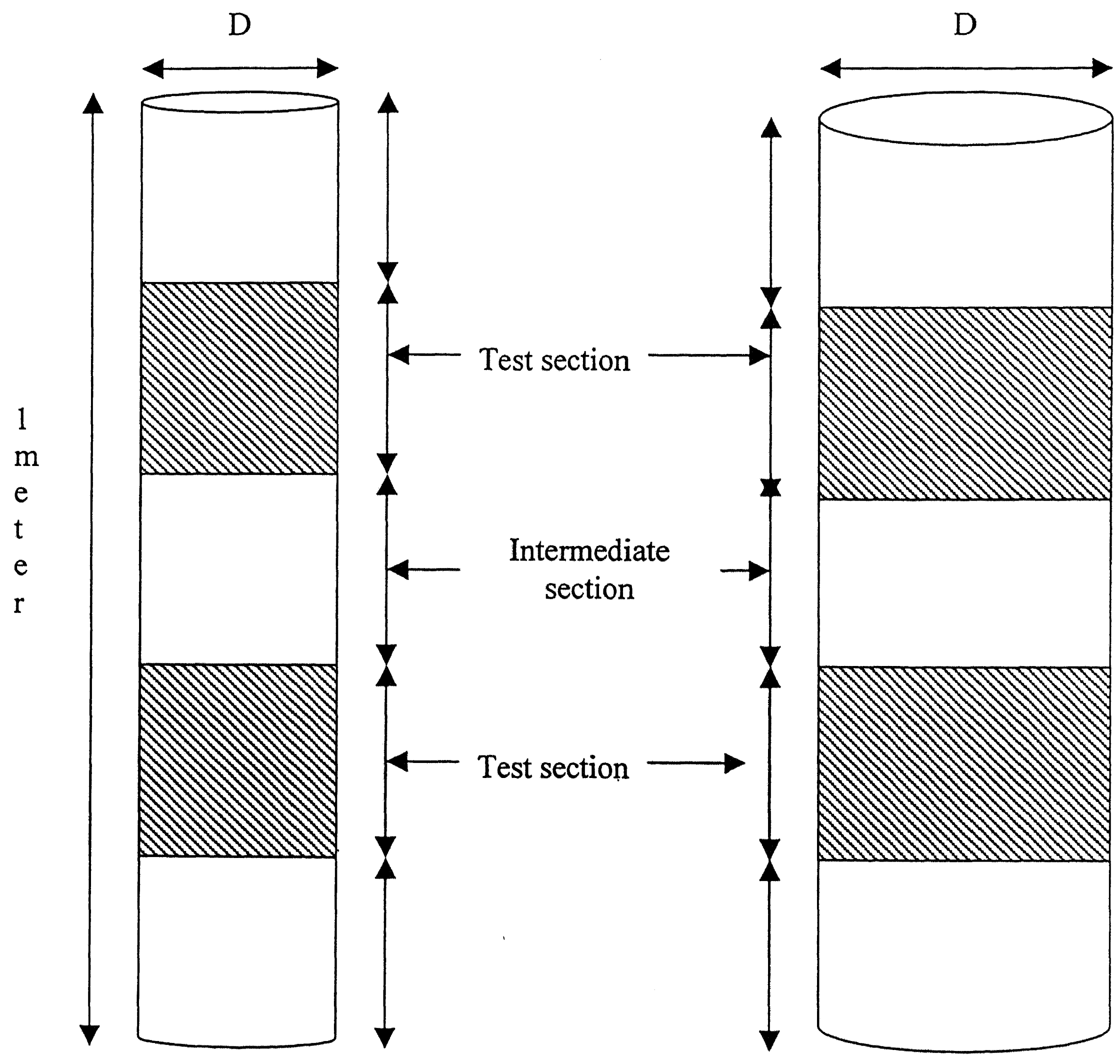


Fig 3.2 Diagram showing the different sections of the fall tubes.

Table3.3 Dimensions of the fall tubes.

Tube Number	Diameter, D(mm)	Length, H (meter)
1	40.6	1.2
2	50.5	1.2
3	57.5	1
4	75.6	1
5	9.5 94.5	1

3.2 SETTLING EXPERIMENTS

Test liquids were loaded in the fall tubes and the test particles were soaked in the liquid at least 24 hours prior to the experiment, thereby allowing the air bubbles to escape and the thermal equilibrium to be reached .During this period, the open ends of the fall tubes were covered with lids to minimize the evaporation losses. Each tube was ensured to be vertical within $\pm 0.5^\circ$, with the use of a spirit level.

Test particles (without any air bubble attached to them) were introduced into the fall tube beneath the liquid surface with their axis parallel to that of the fall tube and as close to its centre as possible. Only those results were accepted for which the concordant fall times were obtained. At least three particles of each dimension were used in the experiment and the average value is taken to minimize the experimental uncertainty. The terminal velocity of a particle was measured by timing its fall over two test sections, using a "stop watch" reading up to 0.01 seconds. In addition to the quantitative time measurement, the orientation or a change in it during settling was visually recorded. Broadly speaking, the orientation of the object is found to be dependent on the apex angle of the falling cones. It was observed for cones, with apex angle, (2α), less than 53, fall with their tips pointing upward, otherwise, cones with apex angle higher than 53, change their orientation and fall vertically with the tip pointing downward.

3.3 DATA ANALYSIS

3.3.1 Equivalent Diameter

Different definitions of diameter for the non-spherical particles are used here, in the form of equivalent diameter, nominal diameter, etc to make the calculation of non-spherical particles analogous to that for spherical particles.

An equivalent diameter, d_{eq}, is defined as the diameter of the sphere with the same volume as that of the non-spherical (in our case conical) particle.

The volume of a cone, with base diameter d and height h, is given as,

$$V=\pi d^2h/12 \tag{3.2}$$

$$d_{eq}=(d^2h/2)^{1/3} \tag{3.3}$$

Another definition of diameter is expressed as nominal diameter, d_n, which is defined as the diameter of a sphere with the same projected area (A_p) as that of the non-spherical particle. Here, in our case, d_n=d, d being the base diameter of the conical particle. The projected area (A_p) is given as

$$A_p= \pi d^2/4 \tag{3.4}$$

A shape factor, sphericity (ψ), is defined as the ratio of the surface area of a sphere with same equivalent diameter to that of the particle under consideration. In our case of conical particles,

$$\psi = \frac{\pi d_{eq}^2}{\dfrac{\pi d^2}{4} + \dfrac{\pi d\left(\left(\dfrac{d}{2}\right)^2 + h^2\right)^{1/2}}{2}} \tag{3.5}$$

3.3.2 Wall Correction Factor, f_w

From the knowledge of fall times, terminal velocity of each particle was calculated as a function of diameter ratio, (d/D). The measured terminal velocity for cones ranges from 0.6 mm/s to 0.75 m/s in Newtonian media, and 0.21 mm/sec and 0.93 m/s in non-Newtonian media. Wall factor, f_w , is defined as the ratio of terminal velocity of a particle in a bounded medium (v) to that in an infinite expanse for the same test fluid (V_∞) namely

$$f_w= v/V_\infty \tag{3.6}$$

Evidently, the wall factor f_w will vary in between 0 to 1. For a given test particle /liquid combination, the terminal velocity in the unbounded medium (V_∞) is estimated by extrapolating the v-(d/D)plot to (d/D)=0 .This in turn allows the value f_w to be calculated as a function of the kinematic variables, diameter ratio and physical properties of test liquids for each individual particle drop test.

3.3.3 Drag Coefficient

At steady fall condition, the drag coefficient (defined in the usual manner) is obtained by writing a force balance on the particle

$$C_{D\infty} = \frac{F_D / A_P}{V_\infty^2 \rho_f / 2} \tag{3.7a}$$

$$C_{D\infty} = \frac{m_P g\left(1 - \rho_f / \rho_P\right)}{0.5 \rho_f V_\infty^2 A_P} \tag{3.7b}$$

Where A_P is the projected area of particle normal to the direction of fall and is equal to $(\pi d^2 / 4)$ irrespective of whether a cone settles with its apex upwards or downwards. One would expect the drag coefficient to be a function of the Reynolds number and (h/d) or α, hence one can write

$$C_{D\infty} = f\,(Re_\infty, \alpha) \tag{3.8}$$

3.3.4 Reynolds Number

For power law fluid, Reynolds number, Re_∞' is defined as

$$Re_\infty' = \frac{\rho_f V_\infty^{2-n} d_{eq}^{\ n}}{k} \tag{3.9}$$

Which reduces to the expected definition of Reynolds number for n=1 in case of Newtonian fluid

$$Re_\infty = \frac{d_{eq} \rho_f V_\infty}{\mu} \tag{3.10}$$

This approach to the correction of the data for non-spherical particles has been employed successfully in the literature ([12-14], [16-19]). Another method which has also been used in our study is by correlating the terminal velocity data for non-spherical particle is through the use of a velocity factor. In this approach the behavior of a non-spherical particle is contrasted with that of an equivalent sphere and some other geometric ratios characterizing the shape in relation to a sphere. The works of [16-20], [22] exemplify the usefulness of this approach. Using dimensional considerations, one can postulate the following functional relationships

$$K' = f(\psi, d/D) \tag{3.11}$$

The advantage of this approach lies in the fact that the methods for estimating the free fall velocity of spherical particle in Newtonian fluid are well established for most conditions of practical interest (Clift *et al.* [3], Khan and Richardson [60]) etc. Khan and Richardson [60] proposed an interesting method to terminal velocity of a sphere of any specific diameter and material. They correlated the Archimedes number and Reynolds number of the falling sphere. The Archimedes number is defined as,

$$Ar = \frac{4g\rho_f(\rho_p - \rho_f)d_s^3}{3\mu_f^2} = C_D \,\mathrm{Re}^2 \tag{3.12a}$$

$$\mathrm{Re}_\infty = \left(2.342Ar^{0.018} - 1.523Ar^{-0.016}\right)^{13.3} \tag{3.12b}$$

The terminal velocity v_∞ can be obtained as

$$v_\infty = \frac{\mathrm{Re}_\infty \mu}{d_{eq}\rho_f} \tag{3.12c}$$

Hence, K′ can be found out for any test particle of specific diameter and material, as a ratio of fall velocity as observed in the experiment and the velocity found from Eq (3.12) for a particular Newtonian test fluid.

However, for non-Newtonian fluid it is more complicated to estimate the fall velocity of sphere due to the highly complex nature of the fluid. Renaud *et al.* [61] in their unpublished work put forward the drag coefficient for a sphere, C_{D_∞}, as a function of X, α', b, α_o, β, k etc. Where, the relation between these variables goes as,

$$C_D = C_{D0} + \frac{A_c}{A_m} C_{D\infty} C_{D0}^{2\beta} k^{'} \left[\frac{6Xb}{6Xb + C_{D0}} \right]^{\beta} + C_{D\infty} \left[\frac{6bX}{6bX + 128C_{D0}} \right]^{11/12} \tag{3.13a}$$

Where,

$$\frac{A_C}{A_m} = \frac{\pi d^2}{\frac{\pi d^2}{4}} = 4 \tag{3.13b}$$

$$C_{D0} = \frac{24X}{\mathrm{Re}^{'}} \tag{3.13c}$$

$$X = (0.992)6^{\frac{n-1}{2}} \left(\frac{3}{n^2 + n + 1} \right)^{n+1} \tag{3.13d}$$

$$\alpha' = \frac{3 \times 0.995}{n^2 + n + 1} \tag{3.13e}$$

$$C_{D_\infty} = 0.44 \tag{3.13f}$$

$$b = \exp^{3(\alpha - \ln 6)} \tag{3.13g}$$

$$k^{'} = \frac{\alpha_0 - \alpha'}{2\alpha_0 \alpha'} \exp\left[3(\frac{\alpha_0 - \alpha'}{2\alpha_0 \alpha'}) \ln 3 \right] \tag{3.13h}$$

$$\beta = \frac{11}{48}\sqrt{6} \left[1 - \exp\left\{ \left(\frac{\alpha_0 - \alpha'}{\alpha'(\alpha_0 - 1)} \right)^2 \ln \frac{\sqrt{6} - 1}{\sqrt{6}} \right\} \right] \tag{3.13i}$$

$$\alpha_o = 3 \tag{3.13j}$$

Where, C_{D_∞} and Re'_∞ are given by Eq (3.7) and Eq(3.9) respectively. For a given sphere, with known values of diameter, d_{eq} and density ρ_p, in a test fluid, with known values of ρ_f, n and k, terminal velocity can be found out using Eq (3.7), Eq(3.9) and Eq (3.13),together and applying trial and error method.

Both the aforementioned approaches have been employed to analyze the data on fall velocities of cones gathered in this investigation. Hence all data were converted into dimensionless quantities such as C_{D_∞} ,$\mathrm{Re}^{'}_{\infty}$, f_w ,α, ψ, , d/D etc.

3.3.5 Experimental Uncertainty

All experiments reported in this work have been carried out with utmost caution but still some extent of error is impossible to avoid. Errors can be encountered at different stages of the experimentation, for example, while measuring the dimensions of the particles, density of both test particles and the test liquids, the viscosity of the test fluid, in the recording of the fall time reading of the test particles. Extensive experiments were performed with sphere and compared with previous results in Newtonian media [3], [32] as well as non-Newtonian media [36, 37], [49] for both drag calculations and wall correction factor, to calibrate the results and experimental uncertainty for non-spherical particles.

For further checking the reliability of our experimental results for non-spherical particles, a shape factor analysis is carried out and Reynolds number based on effective diameter is defined. The drag results corrected for wall effects of cones have been therefore compared with sphere results, using Eq(3.13), for both Newtonian as well as non-Newtonian media. The effective diameter d_{eff}, is defined in the following manner.

For a-sphere,

Volume, $V = \dfrac{\pi d^3}{6}$ (3.14a)

Surface area, $A = \pi d^2$ (3.14b)

Specific surface area is defined as, $A_s = \dfrac{A}{V} = \dfrac{\pi d^2}{\pi d^3/6} = 6/d$ (3.14c)

Hence, d_{eff} is defined by, $d_{eff} = 6/A_s$ (3.14d)

In case of a cone, the total surface area is given by,

$$A = \frac{\pi d^2}{4} + \frac{\pi d}{2}\left\{\left(d/2\right)^2 + h^2\right\}^{1/2} \tag{3.14e}$$

The volume of a cone is given by, $V = \pi d^2 h/12$ (3.14f)

Hence, the specific surface area of a cone,

$$A_s = A/V = \left.\frac{\pi d^2}{4} + \frac{\pi d}{2}\left\{\left(d/2\right)^2 + h^2\right\}^{1/2} \middle/ \pi d^2 h/12\right. \tag{3.14g}$$

$$A_s = \frac{3\left[1+\left\{1+\left(\frac{2h}{d}\right)^2\right\}^{1/2}\right]}{h} \tag{3.14h}$$

Hence, the effective diameter for a cone is defined as,

$$d_{eff} = 6/A_s = \frac{2h}{\left[1+\left\{1+\left(\frac{2h}{d}\right)^2\right\}^{1/2}\right]} \tag{3.14i}$$

Now we can define Reynolds number for Newtonian fluids as,

$$\mathrm{Re}_{deff} = \frac{d_{eff}\,\rho_f\,v}{\mu} \tag{3.14j}$$

And for non-Newtonian fluid we can define Reynolds number as,

$$\mathrm{Re}'_{eff} = \frac{(v)^{2-n}\,d_{eff}^{n}\,\rho_f}{k} \tag{3.14h}$$

The detailed analysis of experimental uncertainty is presented in the chapter 4.

Chapter 4

RESULTS AND DISCUSSION

4.1 RHEOLOGICAL PROPERTIES OF TEST MEDIA

As expected, castor oil, silicone oil, glycerol and sugar solutions displayed the Newtonian flow characteristic; the resulting values of viscosity along with other physical properties are presented in the Table 3.1. It is clearly seen that the viscosity varies by four orders of magnitude.

Typical shear stress–shear rate for the aqueous solutions of Carboxymethyl Cellulose (CMC), and Methocel used in this study are shown in Figures 4.1 and 4.2. All solutions showed shear thinning characteristics. Although, the test liquids were not checked for possible viscoelastic effects, but these were likely to be negligible due to relatively low molecular weight as well as low concentration of polymers used in this study. An examination of viscometric study as shown in fig (4.1) and fig (4.2) suggested that the usual two parameter power law model can be used to adequately represent the shear thinning viscosity.

$$\tau = k\,(\gamma)^n \qquad (4.1)$$

The resulting values of n and k and the other physical properties of polymer solutions are given in table 3.1. The physical properties of all the test liquids were measured at the same temperature as that encountered in settling experiments.

4.2 CALIBRATION RESULTS

Initially, extensive experiments were carried with spheres in both Newtonian and non-Newtonian media to ensure the reliability of the experimental technique and to gauge the overall accuracy of the results. Since prior reliable results are available for sphere both in Newtonian and non-Newtonian media, for drag as well as for wall effects, it is always safe to

check the experimental results and technique and also to calibrate for experimental uncertainty, even for non-spherical particle with the use of sphere results.

All the experimental data are compared with the predicted values from prior studies and the maximum and average deviations are calculated. The deviation in the further discussion is defined as

=100(Predicted value-Experimental value)/ Predicted value.

4.2.1 Newtonian Media

4.2.1.1 Wall Effects

The experimental results for f_w at various values of λ, (λ=d/D) for $Re_\infty<1$, are shown in the fig (4.3). These results are compared with the theoretical expression as suggested by Haberman and Sayre [62]. The correlation of Haberman and Sayre [62] goes thus,

$$f_w = \frac{1-2.105\lambda+2.0865\lambda^3-1.7068\lambda^5-0.72603\lambda^6}{1-0.75857\lambda^5} \tag{4.2}$$

The experimental values are observed to lie within ±10% range.

For $Re_\infty>1$, the influence of Reynolds number (Re_∞), on f_w is quite obvious. Fig (4.4) shows the comparison of our experimental values with the predicted values, as suggested by DiFelice [63], based on his experimental results. The correlation by DiFelice is given by,

$$f_w = \left(\frac{1-\lambda}{1-0.33\lambda}\right)^{\alpha} \tag{4.3.a}$$

Also, α is related to the terminal Reynolds number as

$$\frac{3.3-\alpha}{\alpha-0.85} = 0.1\,\mathrm{Re}_\infty \tag{4.3.b}$$

The maximum and average deviations found between predicted and experimental values are 26% and 7% respectively.

4.2.1.2 Drag

Fig (4.5) shows the experimental results of $C_{D\infty}$ against Re_∞ for sphere. The experimental results are compared with the correlation proposed by Khan and Richarson [60];

the average and maximum deviations found are 5% and 12% respectively. The correlation of Khan and Richardson is given as,

$$C_{D\infty} = (2.25\,\mathrm{Re}_{\infty}^{-0.31} + 0.36\,\mathrm{Re}_{\infty}^{0.06})^{3.45} \quad , \qquad 10^{-2} < \mathrm{Re}_{\infty} < 10^{5} \tag{4.4}$$

4.2.2 Non–Newtonian Media

4.2.2.1 Wall Effects:

For wall correction factor calculation, based on experimental study by Chhabra and Uhlherr [64], it is said that the f_w values are independent of Re'_{∞} in lower range of Reynolds number, $\mathrm{Re}'_m \sim 1$, and shows linear dependence on (d/D)

$$f_w = 1 - 1.6(d/D), \qquad (d/D) \leq 0.5 \tag{4.5}$$

Fig (4.6) shows the values of experimental f_w and it is within ±10% agreement with Eq (4.5). However, they further studied the dependence of f_w on Re'_m and observed that in the range $1 < \mathrm{Re}'_m < 1000$, Re'_m has very high influence on f_w. Uhlherr and Chhabra [65] after extensive experimental studies in the range of conditions, $0.5 \leq n \leq 1$; $0.2 \leq \mathrm{Re}'_m \leq 1000$; $(d/D) \leq 0.5$, proposed that the wall effect can be empirically correlated to the diameter ratio (d/D) and the Reynolds number as,

$$\frac{(1/f) - (1/f_{\infty})}{(1/f_0) - (1/f_{\infty})} = \left[1 + 1.3\,\mathrm{Re}'_m\right]^{-1/3} \tag{4.6}$$

where, f_o and f_∞, the values of wall factor at low and high Reynolds number regions are given by

$$f_o = 1 - 1.6(d/D) \tag{4.6a}$$

$$f_\infty = 1 - 3\,(d/D)^{3.5} \tag{4.6b}$$

Here, Re'_m is the Reynolds number based on measured velocity (v) of the sphere in the confined region. Fig (4.7) shows the comparison of the experimental values with Eq (4.6). A

reasonably good correspondence is seen with an average deviation of 8% and a maximum deviation of 25%.

2.2.2.2 Drag Coefficient

A few experiments were carried out with spherical particles in the power law fluids and the dependence of $C_{D\infty}$ with Reynolds number Re'_∞ is studied.

For $\mathrm{Re}'_\infty \leq 1$, the dependence of $C_{D\infty}$ on Reynolds number can be given by

$$C_{D\infty} = \frac{24X}{\mathrm{Re}'_\infty} \tag{4.7}$$

The values of X depend upon 'n' and are available in the literature. However, for $\mathrm{Re}'_\infty > 1$, not many results are available for sphere in non-Newtonian power law fluid. The present experimental results are compared with Renaud *et al.*[61]. The expression is already given in Eq(3.13).

Fig (4.8) shows the $C_{D\infty}$ vs. Re'_∞ values for $\mathrm{Re}'_\infty \leq 1$. The experimental results are compared with Eq (4.7). The maximum and average deviations found are 7% and 11.5% respectively. The $X = \left(\frac{C_{D\infty}\mathrm{Re}'_\infty}{24}\right)$ value as obtained from the experimental calculation, in the regime $\mathrm{Re}'_\infty \leq 1$, is compared with previously found results as given in table 4.1. Here the average and maximum deviations found are 4.1% and 13.6%.

Table No.4.1 Comparison of X values

n	X (interpolated from prior studies)	$C_{D\infty}\mathrm{Re}'_\infty/24$	% Deviation
0.7196	1.304078	1.315247	-0.85648
0.7196	1.304078	1.194858	8.375238
0.7196	1.304078	1.131083	13.26567
0.7196	1.304078	1.425257	-9.29235
0.7196	1.304078	1.307859	-0.28995
0.7196	1.304078	1.176253	9.801889
0.7196	1.304078	1.126445	13.62133
0.7196	1.304078	1.428089	-9.50954

0.698	1.320148	1.155506	12.4715
0.698	1.320148	1.241869	5.929571
0.698	1.320148	1.172155	11.21036
0.698	1.320148	1.351111	-2.34542
0.698	1.320148	1.310713	0.714731
0.698	1.320148	1.182517	10.42546
0.698	1.320148	1.443867	-9.37161
0.698	1.320148	1.276362	3.316751
0.698	1.320148	1.200088	9.094404
0.698	1.320148	1.212605	8.146319

Fig (4.9) shows the comparison of our experimental results with Eq (3.13). The maximum and average deviations found are 25% and 8.3% respectively.

The main idea, behind the experiments with spherical particles in both Newtonian and non-Newtonian media, is to check the reliability of the experiment technique and to calibrate the experimental uncertainty occurred during the experimentation with non-spherical particles. Based on the calculations for spherical particles and the subsequent comparisons with standard results, we can believe, the present results for non-spherical particles do not entail experimental uncertainty >8-10% for Newtonian media, and >10-12% in non-Newtonian media.

4.3 WALL EFFECTS ON CONICAL PARTICLES:

4.3.1 Newtonian Media:

Fig (4.10) and fig (4.11) shows the typical dependence of the measured terminal velocity on the diameter ratio (d/D) for cones in two different liquids. Clearly, the dependence is seen to be linear and similar to that observed for sphere (Clift *et al.*[3], Balaramkrishna and Chhabra[31]) and for cylinders(Unnikrishnan and Chhabra[16]), for cones (Sharma and Chhabra[17]), for disk and plate (Chhabra *et al.*[19]). Thus, we can extrapolate the results to (d/D) =0 to obtain the corresponding value of V_∞. This in turn, allows the value of wall factor to be calculated for each drop test. Values of Reynolds number, Re_∞ varied from 0.0019 to 507.

By analogy with the results for spheres and cylinders, the wall factor f_w, is likely to be independent of Reynolds number for $Re_\infty \leq 1$ region. Data pertaining to this flow regime are plotted in fig (4.12) for all cones and compared with the correlation provided by Sharma and

Chhabra [17]. A ±10% band accommodates all the data points deviated from the predicted values,

$$f_w = 1 - 1.51(d/D) \quad (4.8)$$

In order to isolate the effects of diameter ratio and the Reynolds number on the wall factor in higher Reynolds number region, f_w vs. Re_∞ values are plotted for constant values of (d/D), such as 0.233 and 0.177, as obtained in our experiment, as in fig(4.13) and fig(4.14). As expected the wall factor seems to attain a constant value above a critical value of Reynolds number (Re_c).This behavior is quantitatively similar to that observed for cylinders (Unnikrishnan and Chhabra [16]).Unfortunately, there is only few limited experimental data showing the dependence of f_w on Re_∞, but no correlation available. However, from the fig (4.15) we can say that with a deviation of ±10%, the following correlation Eq (4.9) accommodates the wall factor results from our experiment for the region $Re_\infty>1$.

$$f_w = 1 - 1.1(d/D). \quad (4.9)$$

Although, there is effect of Reynolds number in the f_w values here, in $1<Re_\infty<Re_c$ region but the ±10% band seems to accommodate the effect and we can roughly estimate the f_w values using Eq (4.9).

Thus, from the fig (4.13) and fig(4.14), one can see with the increase of Re_∞ the corresponding wall effects decreases (i.e. numerical value of f_w increases).This observation is in accordance with the earlier finding for sphere (Clift *et al.*[3]), for cylinders(Unnikrishnan and Chhabra [16]) and also for cones (Sharma and Chhabra[17]).

4.3.2 Non-Newtonian Media

Fig (4.16) and fig (4.17) displays the typical variation of the measured terminal velocity with the diameter ratio (d/D) for cone in two different aqueous solutions namely CMC 1.5% and Methocel 0.75%. The dependence is again seen to be linear, and one can easily extrapolate these plots for d/D=0 and get the corresponding values for V_∞ for each particle and fluid combination. In this case it was expected that the wall factor f_w will depend on 'n' and apex angle, (α) in addition to Re_∞'. However, an initial statistical scrutiny is carried out by minute observation of the experimental data points and the behavior of f_w at different values of n, which showed that the power law index, does not

influent the value of f_w appreciably. As for the apex angle it is seen in non-Newtonian fluid, that above a certain value of $\alpha>50$, the particles moves towards the tube wall and get adhered to it. However for $\alpha<50$, apex angle does not seem to exert any discernable influence on the value of wall correction factor. For low Reynolds number region, $Re'_\infty \leq 1$, it was to find that the f_w values of the conical particles are in good agreement with the well established results of sphere with a deviation of ±10%. Fig (4.18) shows the experimental results of cone compared with the sphere results as given by Eq (4.5).

Here also, like Newtonian fluid, the f_w values are seen to be influenced by Reynolds number as shown by f_w vs. Re'_∞ plots in fig (4.19) and (4.20) for constant values of d/D (0.233 and 0.177).

For a given value of d/D the wall effect is seen to be more severe in case of low Reynolds number and decreases with increase of Re'_∞. However, the f_w is seen to be independent of Re'_∞ after attaining the critical Reynolds number, Re'_c. Further examination showed that the variation of f_w in the region $1< Re'_\infty< Re'_c$ is within ±10% with that for $Re'_\infty> Re'_c$ region. Although, Sharma and Chhabra [17] already suggested correlation for region $Re'_\infty>Re'_c$ we can further extend it to the region $1< Re'_\infty< Re'_c$ with a deviation of ±10% as shown in the fig (4.21).

$$f_w=1-0.93(d/D) \tag{4.10}$$

4.4 DRAG COEFFICIENT

4.4.1 Newtonian Media

The drag coefficient vs. Reynolds number data are plotted in the fig (4.22) for all test particle in Newtonian test liquids. Data are seen to cover nearly 6 decades of Reynolds number. Moreover, the cone apex angle (α) doesn't appear to be significant variable, at least within the range covered in the study. As expected at lower values of Re_∞, the slope $C_{D\infty}$ vs. Re_∞ appear to be constant and gradually changes with higher values of Reynolds number. The comparison of our experimental results with the correlation suggested by Sharma and Chhabra [17] is shown in fig (4.22), the maximum and average deviations seen are 51% and 15% respectively. The correlation is expressed as

$$C_D = \frac{17}{Re_\infty}(1+0.19\,Re_\infty^{0.805}) \tag{4.11}$$

However with the present experimental results, slightly different values of the constants provide somewhat better representation of the data than Eq(4.11).

$$C_{D_\infty} = \frac{16.5}{Re_\infty}\left(1+0.266\,Re_\infty^{0.70}\right) \tag{4.12}$$

The predictions of Eq (4.12) and the experimentally found values are shown in fig (4.23) where the correspondence between experimental and predicted values is moderately good. The average and maximum deviations of the experimental results with correlation results are found to be 12% and 40% respectively. However, a higher deviation between the experimental and predicted results by both Eq (4.11) and Eq (4.12) is seen in case of test liquid with very low viscosity where the particles showed zigzag motion.

Another method for correlating the terminal velocity data for non spherical particle with that of spherical particle, the following expression is found to be useful (Singh and Roychoudhury,[28])

$$K' = a + b\left(\frac{d_{eq}}{d_n}\right)\psi^{0.5} + c\left(\frac{d_{eq}}{d_n}\right)^2\psi \tag{4.13}$$

Where, K′ is defined as the ratio of terminal velocity of a non-spherical particle to that of a spherical particle with the same equivalent diameter and material of construction, in the same liquid.

Khan and Richardson[60] suggested a very interesting method to find the value of free terminal velocity of sphere and the method is expressed in Eq (3.12). The value of K′ is hence found using the experimentally found terminal fall velocity of the cones and the terminal velocity found for sphere using Eq(3.11). Using the linear regression approach, best values of a, b and c for Eq (4.14) are found to be

a=-2.3; b=7.19; c=-4.5;

A maximum and average deviation found between the predicted and experimental values of K′ are 61% and 25% respectively. Out of total 222 points considered for the regression 40 points are found to have deviation higher than 50%.

The reliability of a, b, c values can be checked for a sphere. For a sphere,

$(d_{eq}/d_n)=1$, $K'=1$;

Hence, coefficients of Eq.(4.13), a + b + c =1;

In the present case, a + b + c =-2.3+7.19-4.5=0.39;

In our case, the summation of the coefficients is higher by 39% than the expected value.

4.4.2 Non Newtonian Systems:

For the free settling motion of cone in a power law fluid, the relevant Reynolds number equation is defined by Eq (3.9).

In the present study, Reynolds number value ranges from 0.021 till 140 thereby covering almost 4 orders of magnitude. Fig (4.25) contains the entire (C_{D_∞} -Re'_∞) data obtained with aqueous polymer solutions in this study .The nature of dependence is seen to be qualitatively similar to that for Newtonian fluid. In fact, the same correlation as in Newtonian fluid represents the data quite well with maximum and average deviation of 62% and 20% respectively. Out of the 264 data point, 53 points were found to have deviation higher than 50%.

$$C_{D_\infty} = \frac{16.5}{Re'_\infty}\left(1 + 0.266\, Re'^{0.7}_\infty\right) \qquad (4.14)$$

Here, the larger deviation is seen for the two polymer solutions CMC 0.5% and CMC 0.4% respectively. The particles were observed to undergo zigzag motion is these two solutions. The deviation in the predicted and experimental values is considered to be attributed by this zigzag motion.

Sharma and Chhabra [17], suggested correlation between, $\left(C_{D\infty} - \mathrm{Re}'_{\infty}\right)$, which can be expressed in the following form,

$$C_{D\infty} = \frac{6.89}{\mathrm{Re}'_{d\infty}}\left(1 + 20.87\,\mathrm{Re}'^{0.211}_{d\infty}\right) \tag{4.15}$$

Where $\mathrm{Re}'_{d\infty}$ is based on the cone diameter. A comparison of our experimental results, with Re'_{∞} converted to $\mathrm{Re}'_{d\infty}$, is done with the predicted values of Eq (4.15) as shown in the fig 4.24). The predicted values are found to be higher by almost ten folds than our experimental values. When the experimental data from [17] were used (Sharma [62]), along with the present experimental values, it was surprisingly found to be in the same range as the present values [fig 4.26)]. Hence, Eq (4.15) is seen to differ from both the present work and also from [62], on which it is based upon.

Another method for correlating the terminal velocity data of non spherical particle with that of spherical particle in the non Newtonian media is used in this study. The following expression is used (Singh and Roychoudhury, [28])

$$K' = a + b\left(\frac{d_{eq}}{d_n}\right)\psi^{0.5} + c\left(\frac{d_{eq}}{d_n}\right)^2\psi \tag{4.16}$$

Renaud *et al.* [61] suggested an interesting method to find the velocity of a freely falling sphere as described in Eq (3.13). K′ is found as a ratio of the falling velocity of cone as found in the experiment and the fall velocity of sphere as obtained by using Eq (3.13)

Using the linear regression approach, best values of a, b and c are found to be

a=-3.28; b=8.126; c=-4.4;

A maximum and average deviation found between the predicted and experimental values are 81% and 33% respectively. Out of total 264 points considered for the regression 61 points are found to have deviation higher than 50%.The particles with higher aspect ratio (d/h) are found to have higher deviation.

Here also, when we checked the reliability of the coefficient values, with respect to phere, it was found a + b + c=0.446. Hence, the summation of the calculated coefficients is ıigher than the expected value by 44.6%. The higher deviation in case of non-Newtonian nedia calculation is assumed to be due to higher complications in calculation of terminal ettling velocity for sphere.

.4.3 Verification for Drag on Non-Spherical Particles

The present values of experimental data for cones are further checked with prior orrelations, relating drag coefficient with Reynolds number and sphericity. Chhabra *et al.* [27] valuated the available methods for calculation of drag for non-spherical particles in ıcompressible viscous fluids by making comparisons between the predicted values and xperimental data, and found that the correlation by Ganser [67] to give best predictive values ased on the maximum and overall mean errors. The present values of cones are compared ith the correlation of Ganser [67] as shown in the fig (4.26). The correspondence between the xperimental and predicted values is found to be reasonably good, with maximum and average eviations of 27% and 55%.

The correlation of Ganser [67] is given by

$$\frac{C'_{D\infty}}{K_2} = \frac{24}{\mathrm{Re}_\infty K_1 K_2}\left\{1+0.118(\mathrm{Re}_\infty K_1 K_2)^{0.6567}\right\} + \frac{0.4305}{1+\dfrac{3305}{\mathrm{Re}_\infty K_1 K_2}} \qquad (4.17a)$$

where, K_1 and K_2 are defined as unique function of ψ. The expression for K_1 and K_2 for ometric shapes are given by,

$$K_1 = \left[(1/3)+(2/3)\psi^{-0.5}\right]^{-1} \qquad (4.17b)$$

$$K_2 = 10^{1.8148(-\log\psi)^{0.5743}} \qquad (4.17c)$$

This is important to mention here, the $C'_{D\infty}$ and Re_∞, used in the correlation are based equivalent volume sphere diameter of the non-spherical particle. Hence for the comparison th Eq (4.17), all the $C_{D\infty}$ values of the experimental calculation were converted to $C'_{D\infty}$.

The experimental data for Newtonian and non- Newtonian media are further tested using Reynolds number based on the effective diameter as explained in section 3.3.4. The C_D, vs. Re_{eff} values for cones are compared with Eq(3.13), with n=1, in Newtonian media, for all values of Re_{eff} as shown in fig (4.27). An average deviation of 40% and maximum deviation of 92% is observed with total number of 176 data points.

Applying the same method in non-Newtonian media, as shown in fig (4.28) the average and maximum deviations found are 33.7% and 88% respectively, which is comparable to that for Newtonian liquids.

4.5 ORIENTATION

4.5.1 Newtonian Media:

In case of Newtonian media it is seen that the conical particle with an apex angle higher than 53°, changes its orientation, falls vertically with its tip pointing downwards. However, since the projected area in both the cases i.e. with the tip of the cone upwards or downwards, is same, the orientation does not significantly influence the drag coefficient calculation. In case of wall correction factor also the orientation is not observed to differ in both the cases.

4.5.2 Non –Newtonian Media

In case of non-Newtonian media the behavior of cones with apex angle higher than 53° are found to be very strange. The particles in this case are seen, while changing its orientation, move radially towards the side wall of the tube, until it adheres to the wall. Hence the free fall velocity of such particles could not be determined.

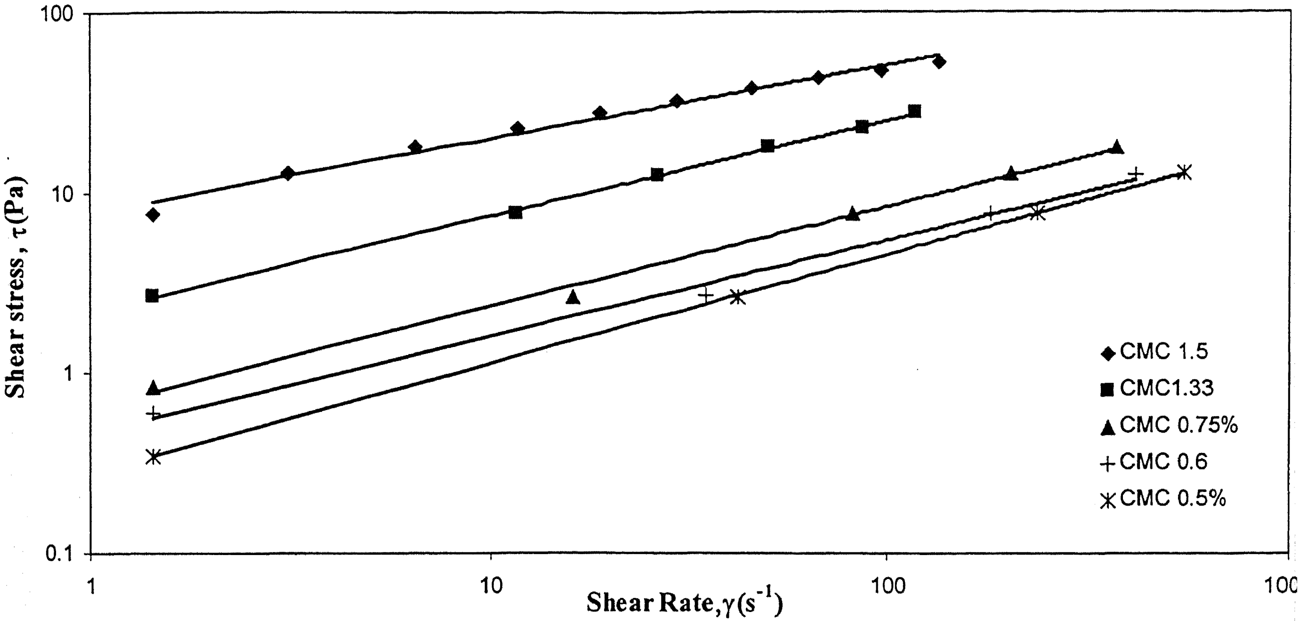


Fig 4.1 Typical shear stress-shear rate data for CMC polymer solutions of different concentrations

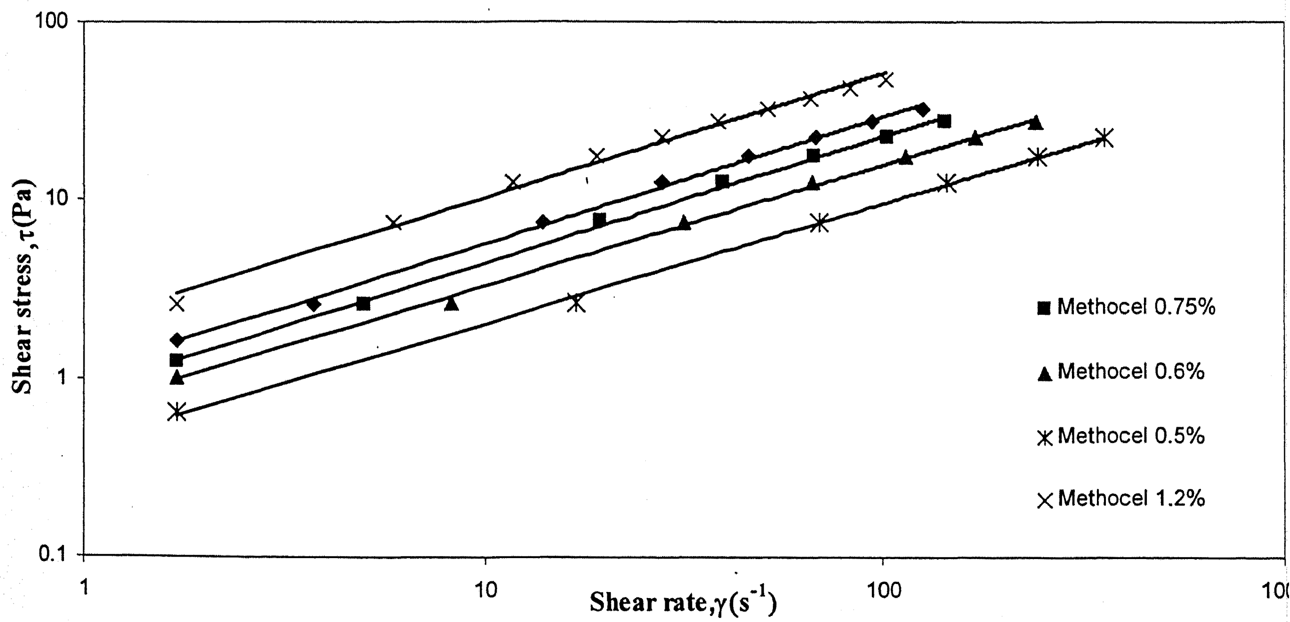


Fig 4.2 Typical shear stress- shear rate data for aqueous Methocel solutions of different concentrations

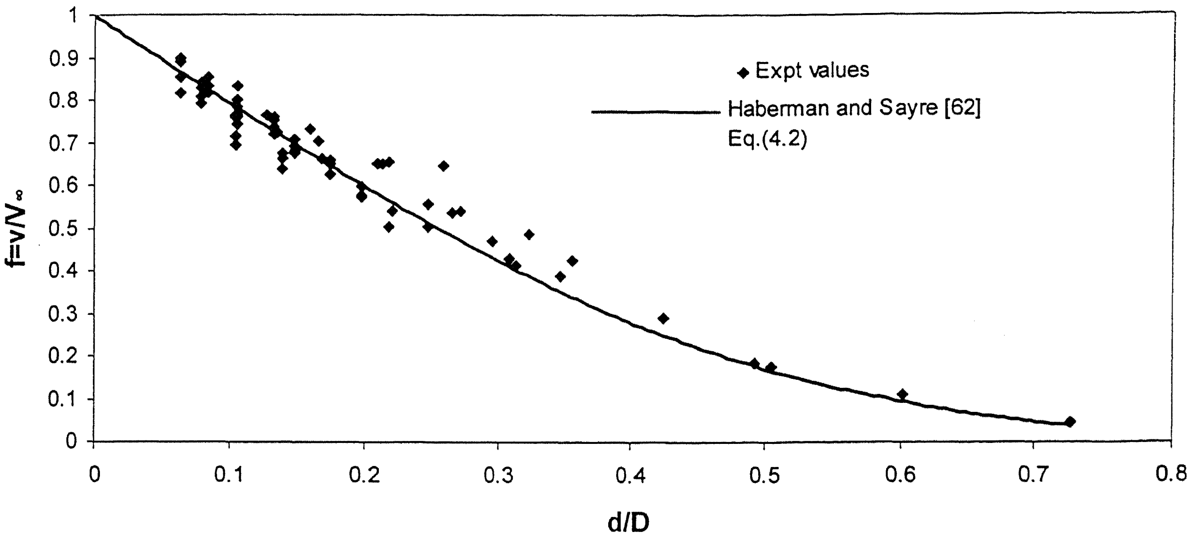


Fig 4.3 Comparison between the present values of wall factor with the predictions of Eq(4.2) for Sphere in the regime $Re_{\infty}<1$

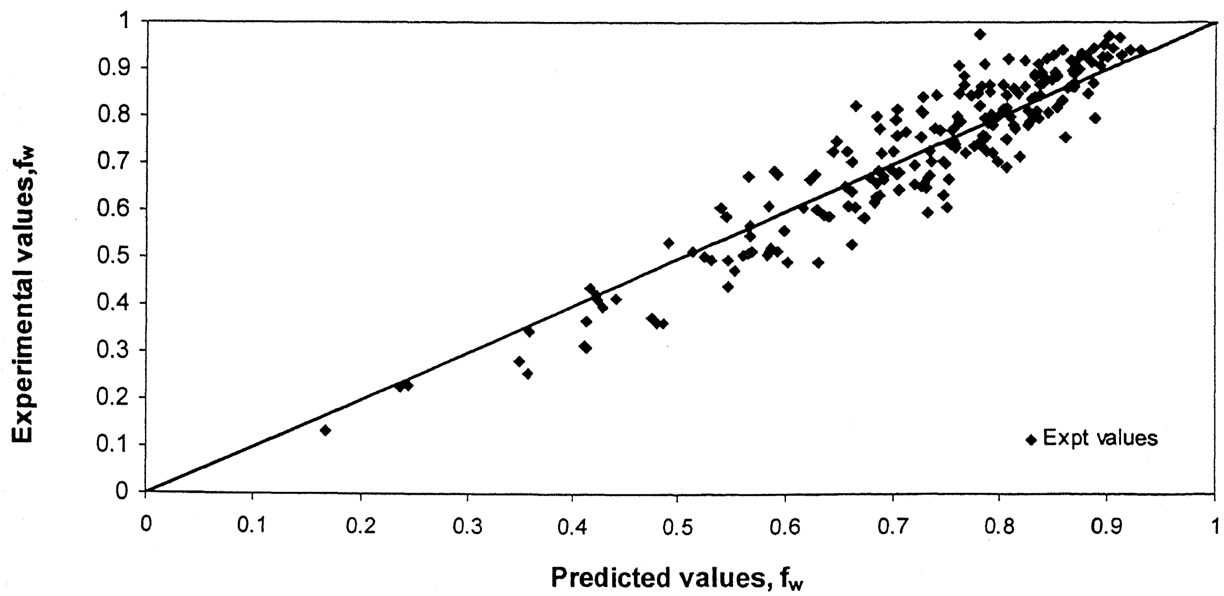


Fig 4.4 Comparison between the present values of wall factor with the predictions of Eq (4.3) for sphere, in regime $Re_{\infty}>1$

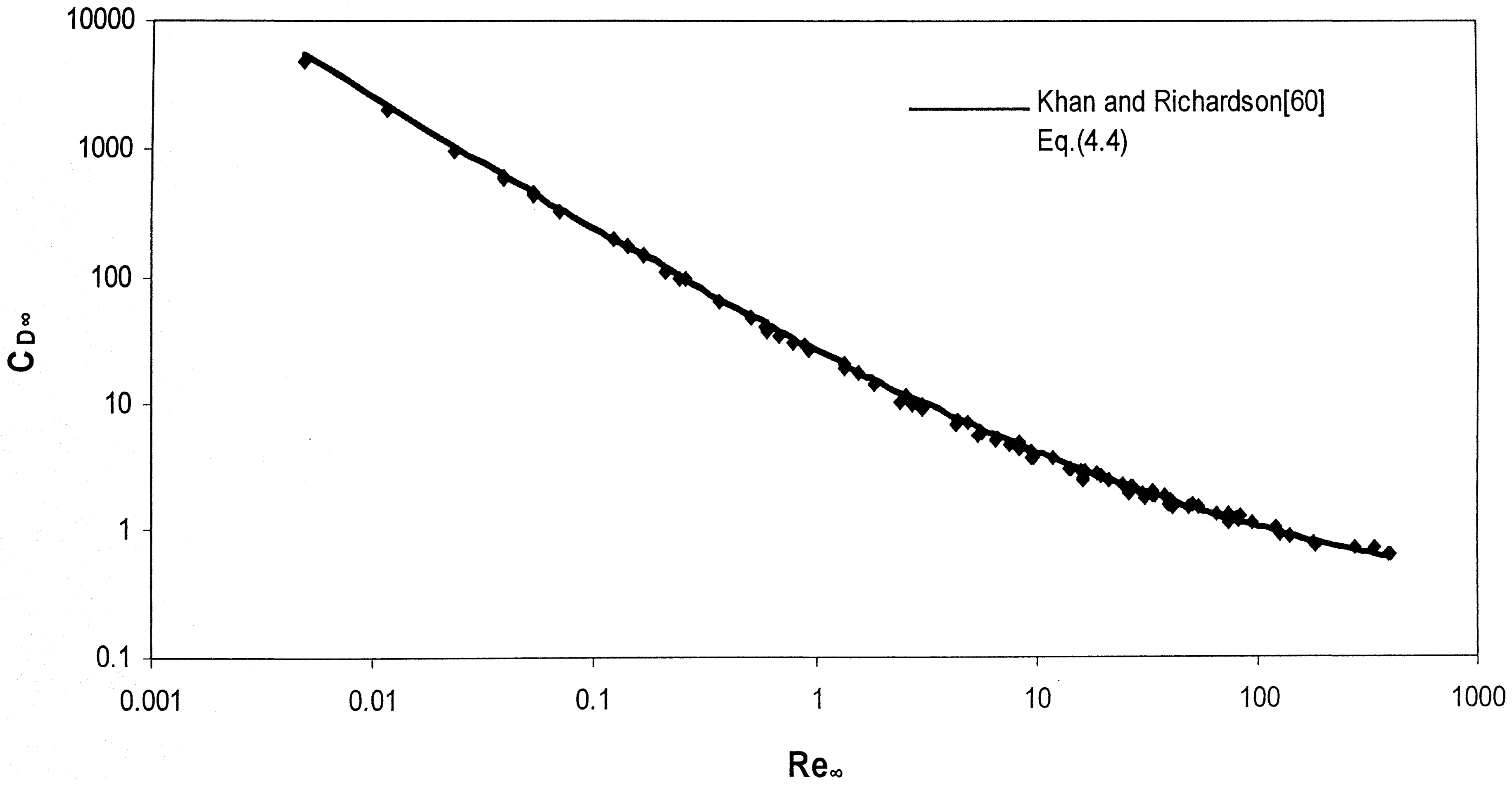
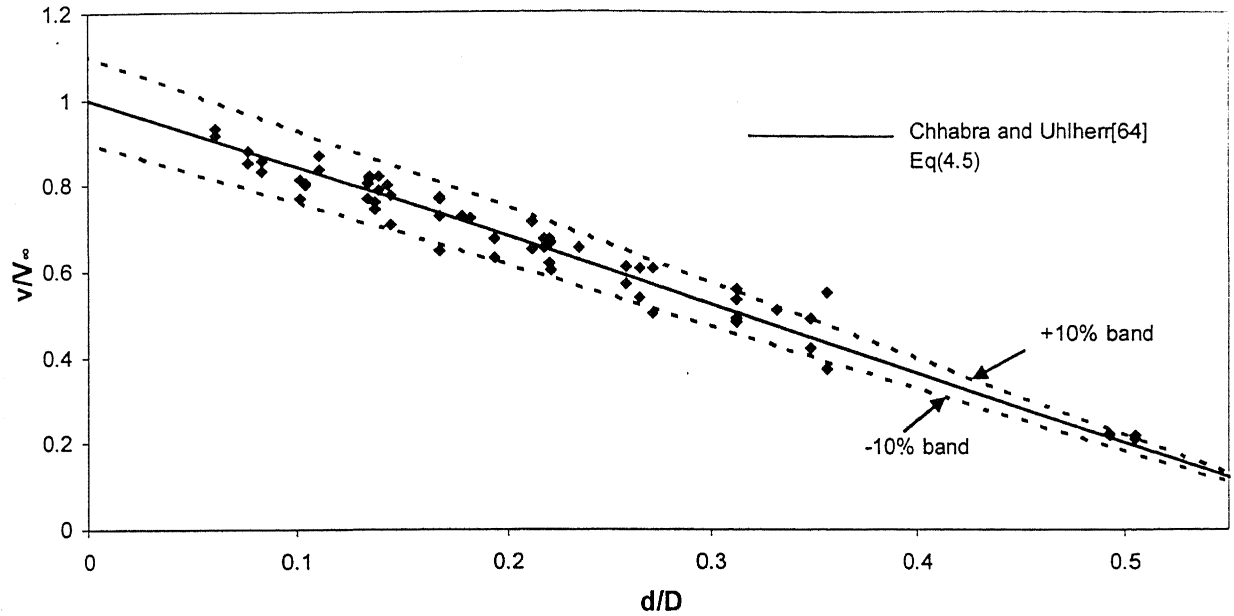
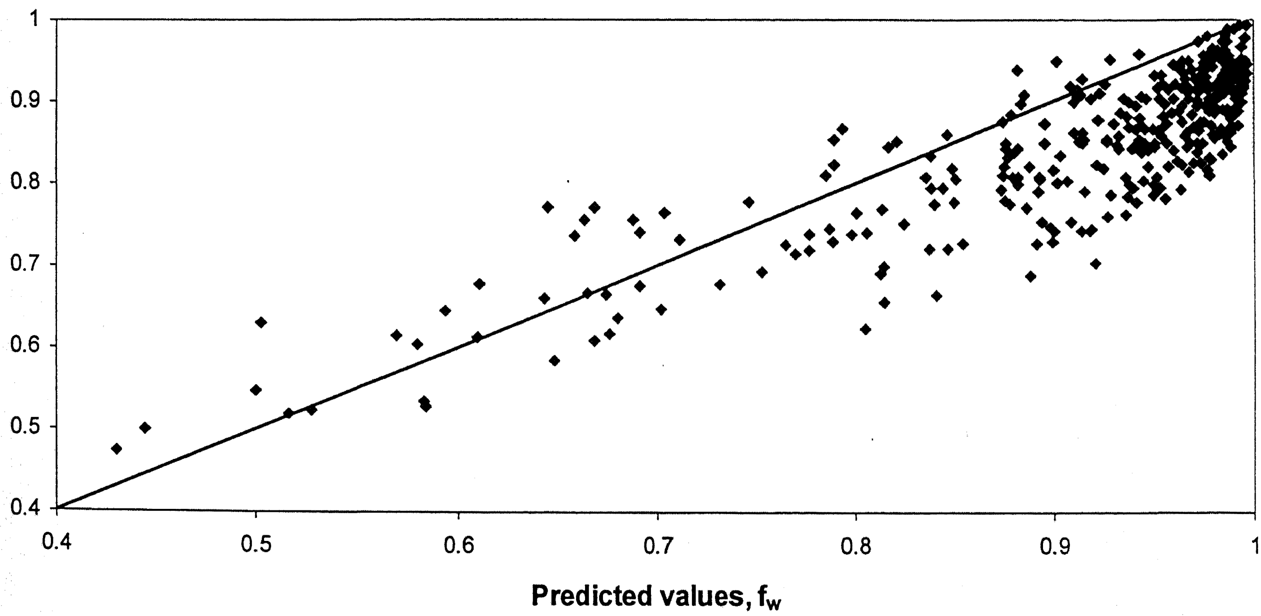


Fig 4.5: Comparison of experimental results for sphere with standard drag curve.



4.6 Comparison of experimental values of sphere wall correction factor with previous results in the regime, $Re'_{\infty} \leq 1$ in non-Newtonian media.



4.7 Comparison between the experimental wall correction factor and predictions Eq (4.6) in the regime $Re'_{m} > 1$

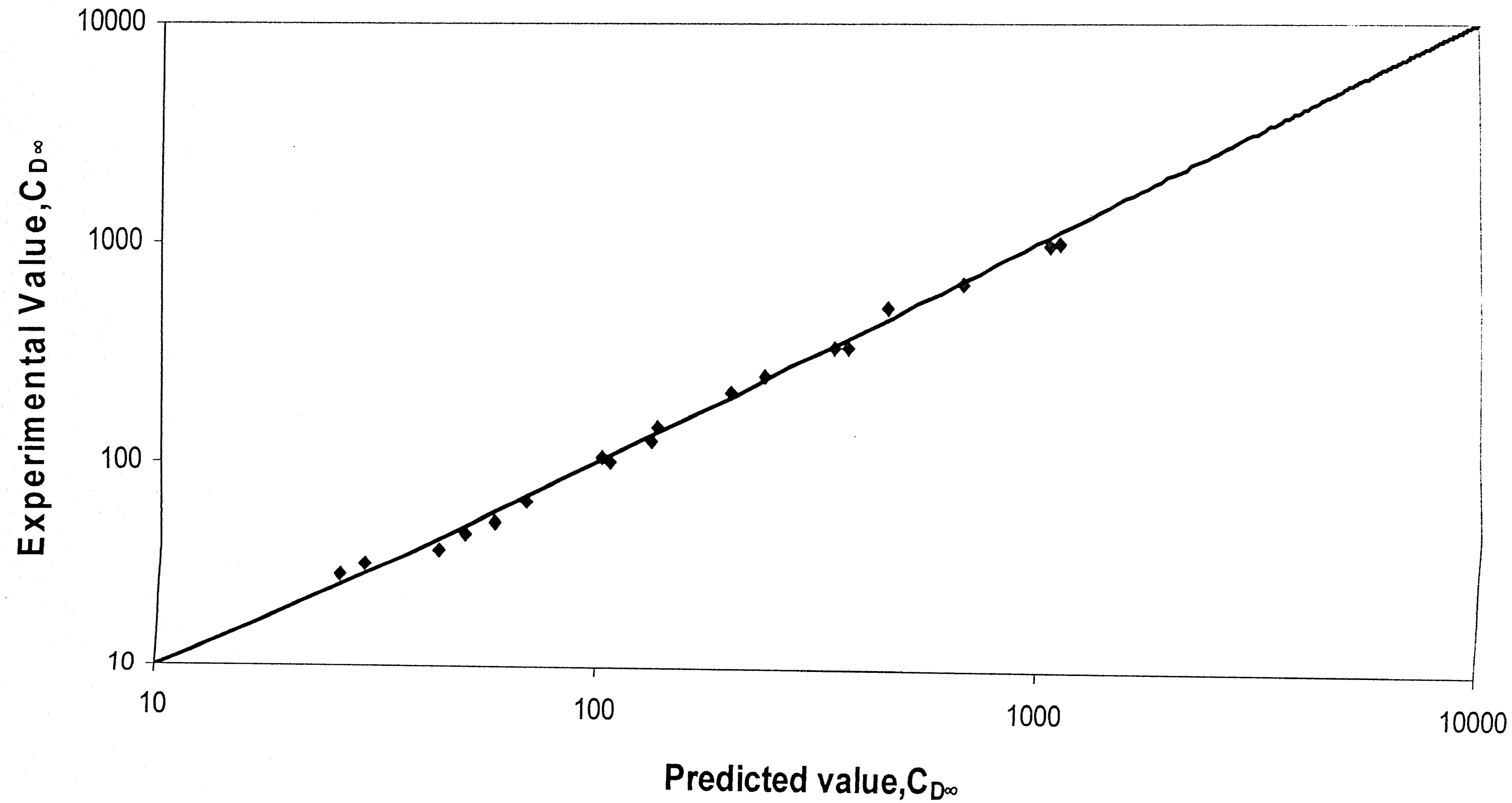


Fig 4.8 Comparison between the predicted values from Eq (4.7) and experimental values of drag coefficient in the regime $Re'_{\infty} \leq 1$

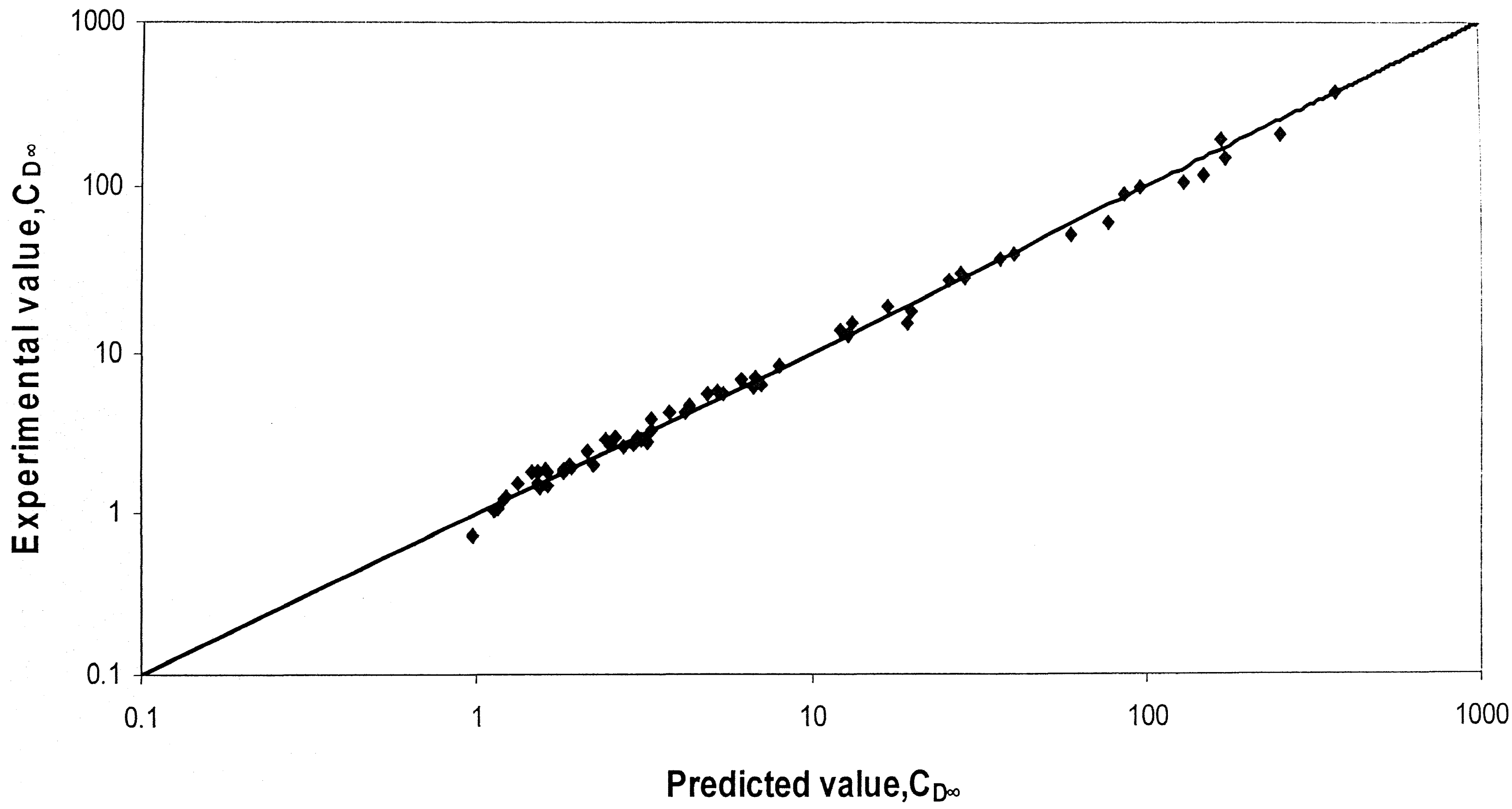


Fig 4.9 Comparison between the predicted values from Eq (3.13) and experimental values of drag coefficient in the regime $0.2 \leq Re'_{\infty} \leq 5000$

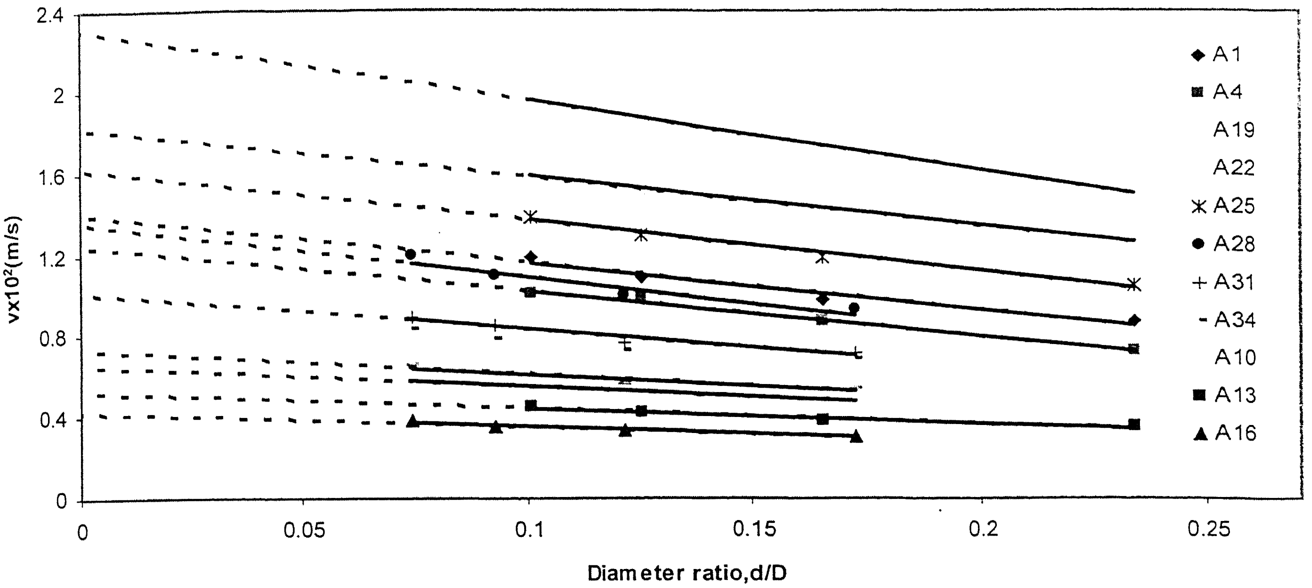
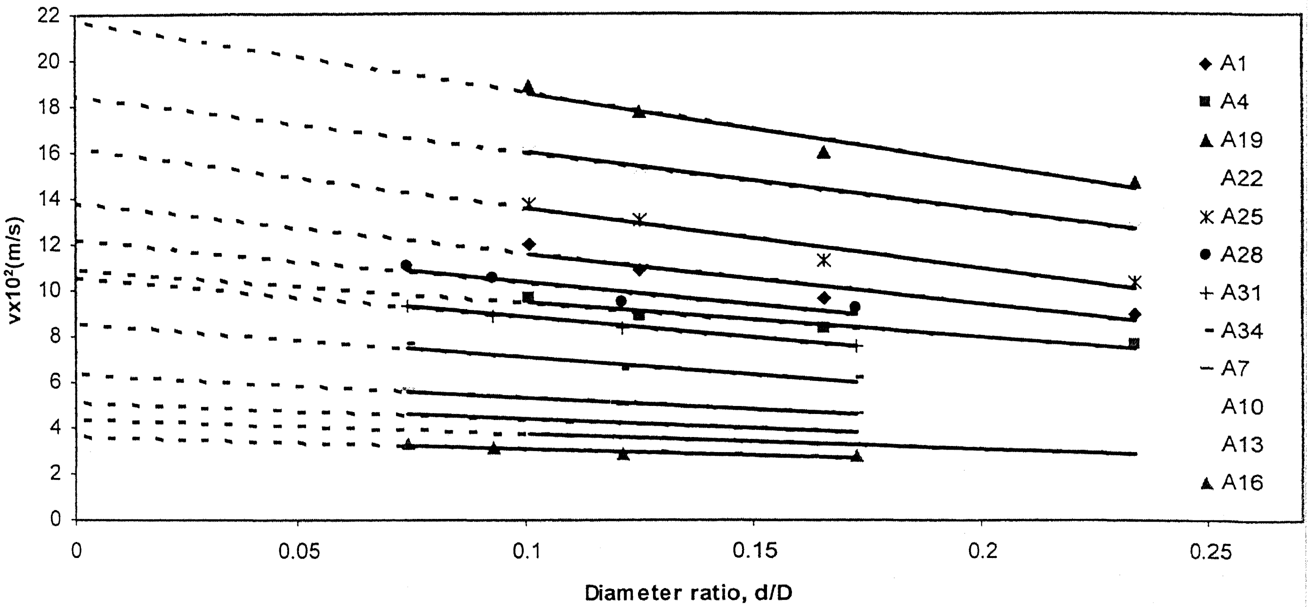


Fig 4.10 Variation of the measured velocity, (v) with the diameter ratio, (d/D) in 90% Glucose solution



4.11 Variation of the measured velocity (v) with diameter ratio (d/D) in Glycerol solution

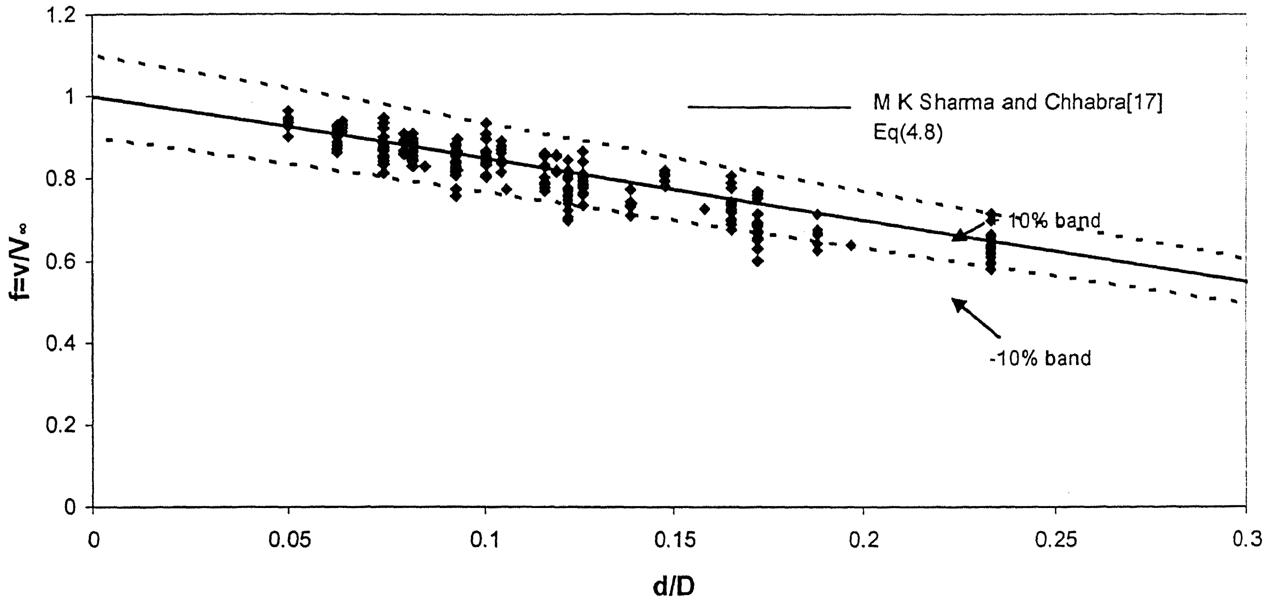
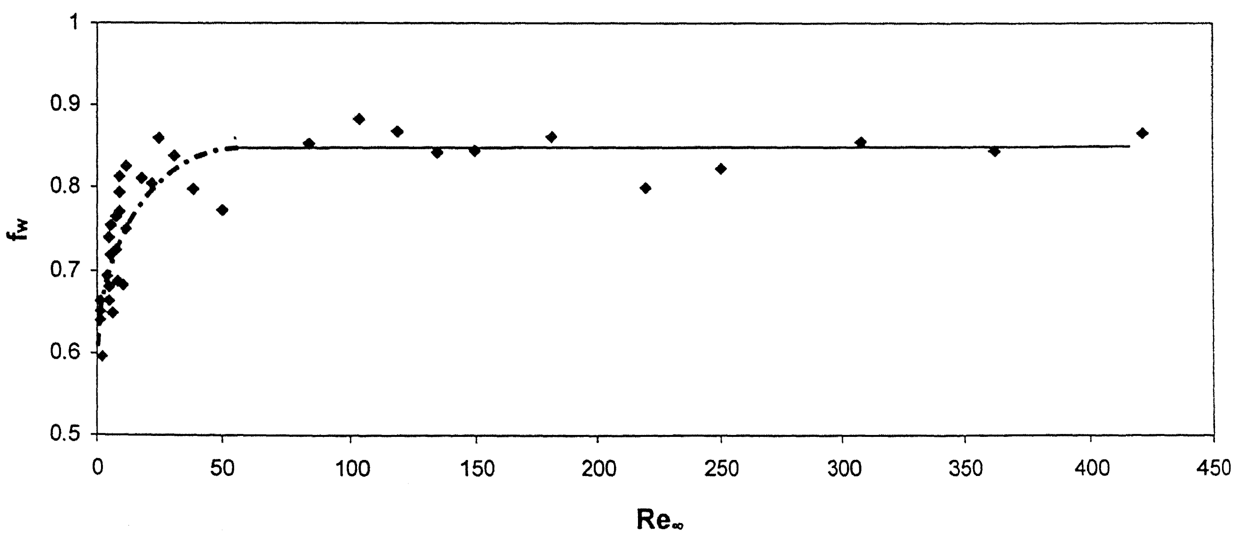
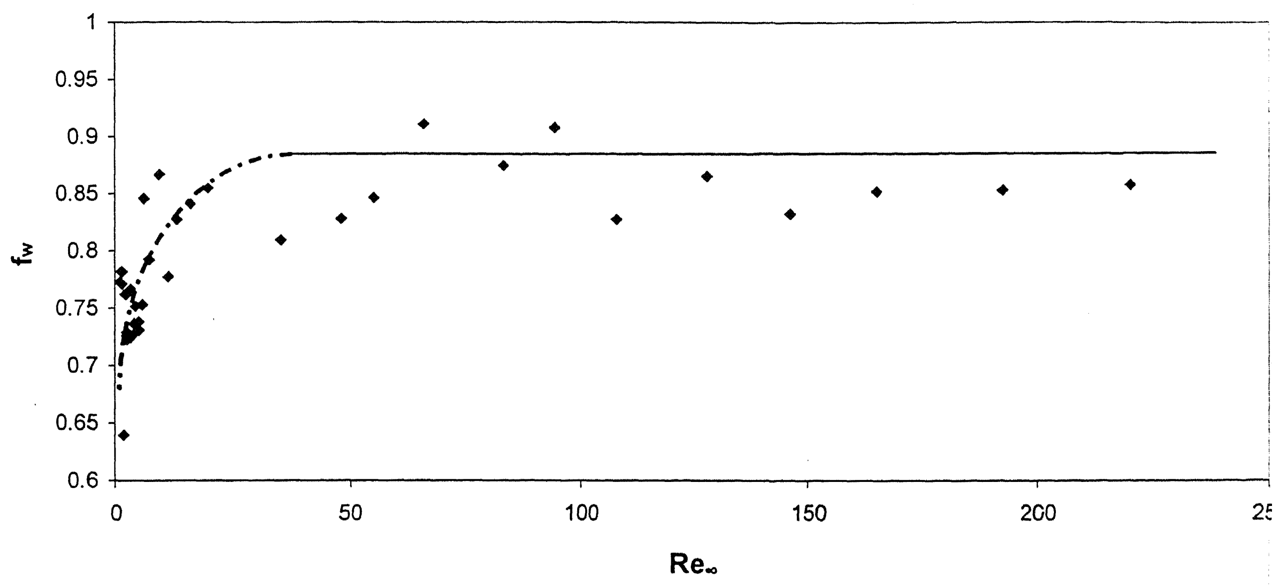


Fig 4.12 Comparison between experimental values of wall correction factor f_w, with predictions of Eq (4.8) for cone.



4.13 Effect of Reynolds number, Re'_∞, on wall correction factor f_w, for $Re'_\infty>1$ regime at constant diameter ratio d/D=0.233. The broken line represents the region where f_w is a function of Reynolds number.



4.14 Effect of Reynolds number, Re'_∞ on wall correction factor f_w, for $Re'_\infty > 1$ regime at constant diameter ratio d/D=0.178. The broken line represents the region where f_w is a function of Reynolds number.

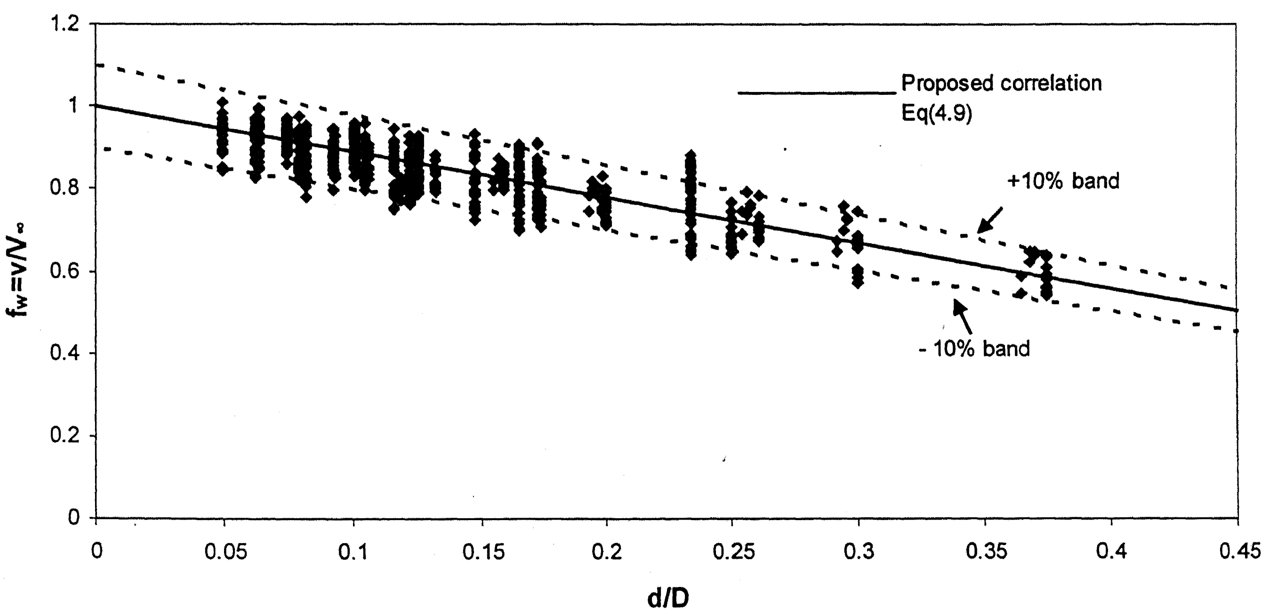
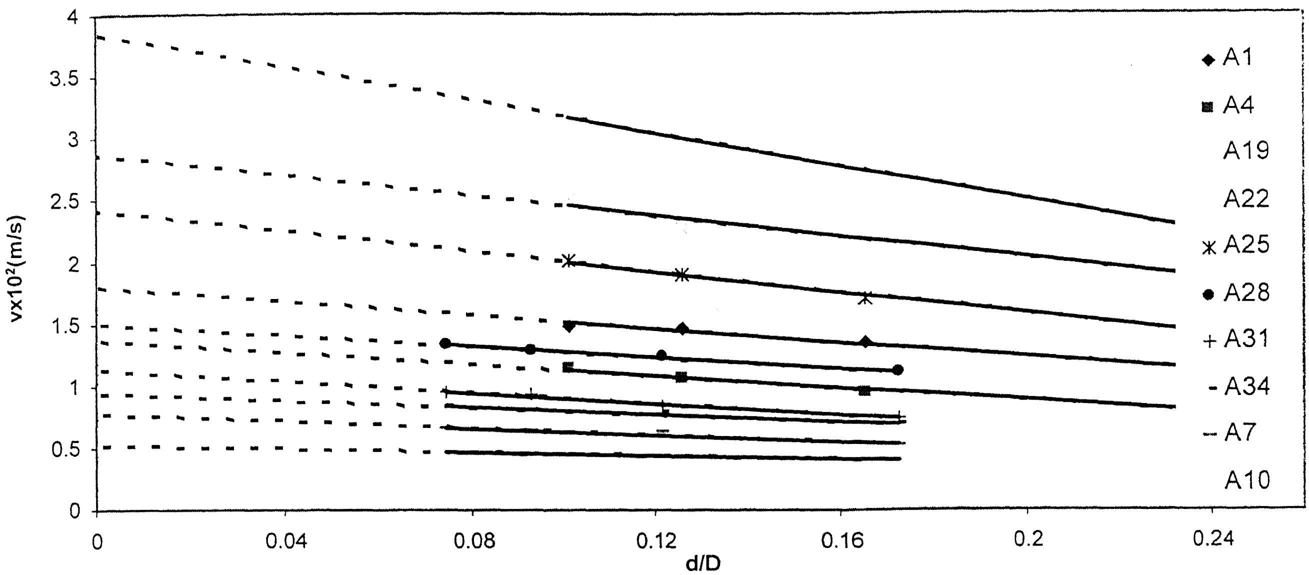
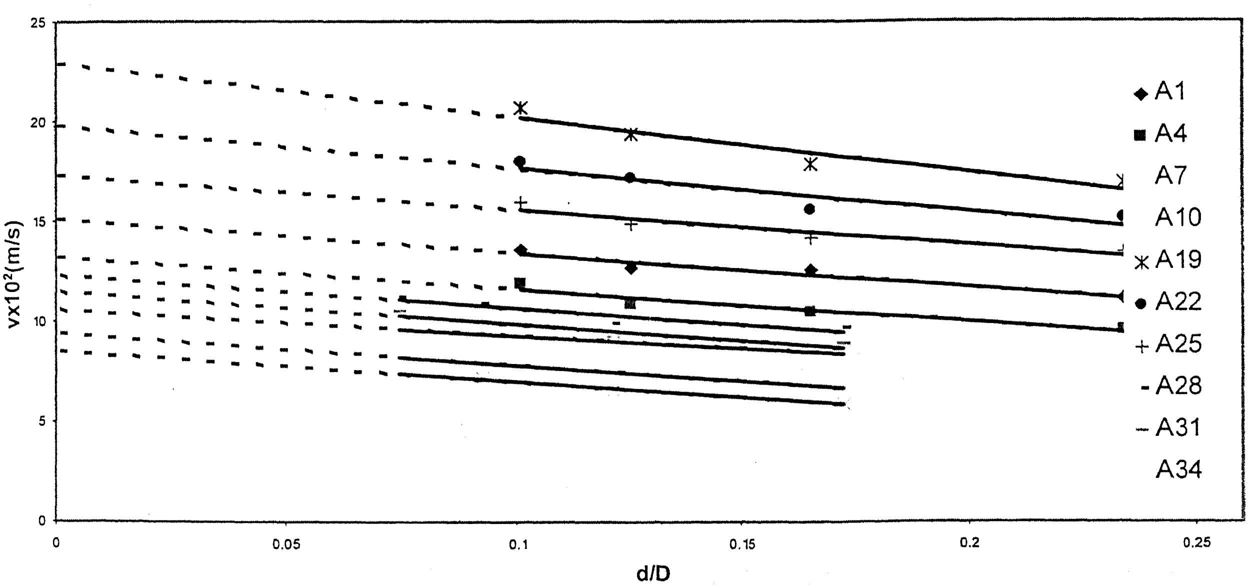


Fig 4.15 Effect of diameter ratio d/D on wall correction factor for cone in $Re'_\infty > 1$ range



4.16 Variation of the terminal velocity with the tube diameter in 1.5% CMC solution



4.17 Variation of the terminal velocity with the tube diameter in 0.75% Methocel solution

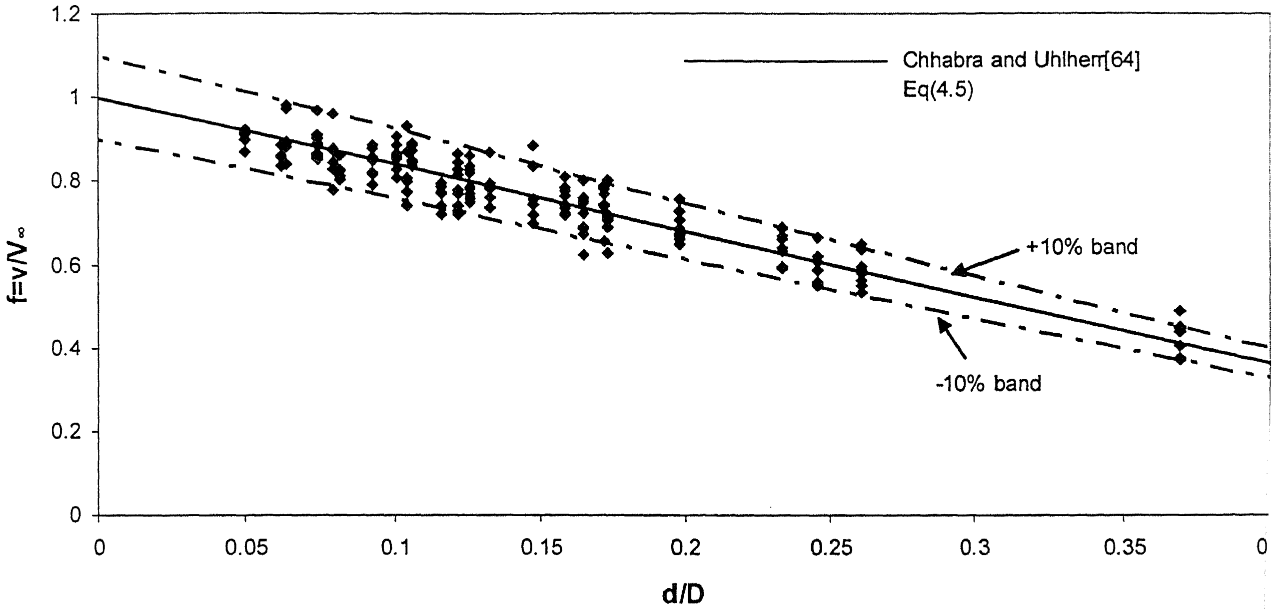
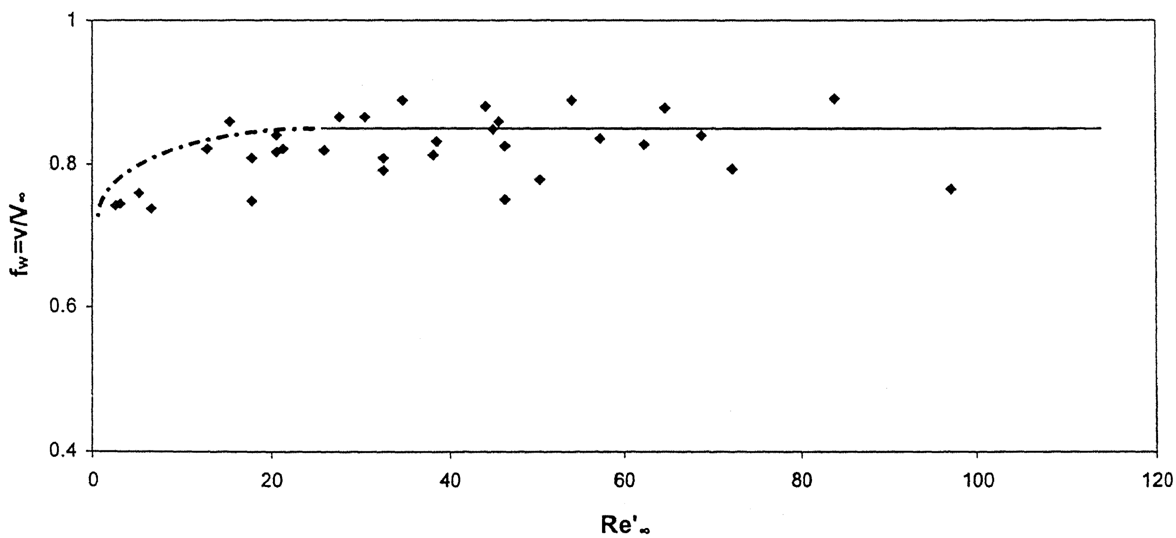
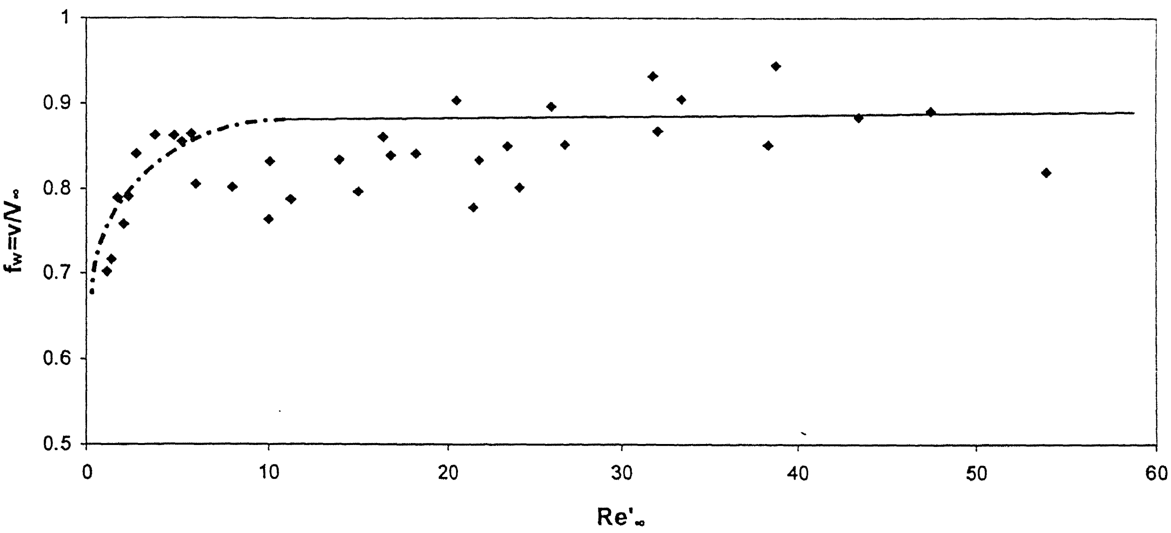


Fig 4.18 Dependence of wall correction factor f_w on diameter ratio (d/D), in the regime $Re_\infty' \leq 1$. The solid line represents Eq (4.5).



4.19 Effect of Reynolds number and on wall correction factor f_w for $Re_\infty'>1$ regime for constant diameter ration d/D=0.234.The broken line represents the region where f_w is a function of Reynolds number, in non-Newtonian media



4.20 Effect of Reynolds number and on wall correction factor f_w for $Re_\infty'>1$ regime for constant diameter ration d/D=0.178.The broken line represents the region where f_w is a function of Reynolds number, in non-Newtonian media

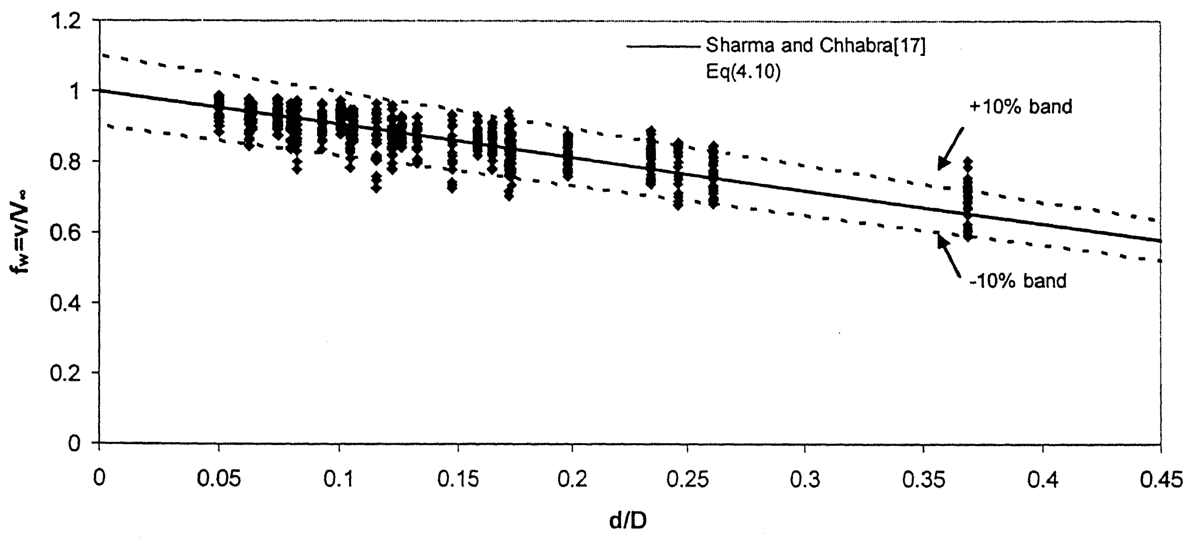


Fig 4.21 Comparison between experimental values of wall correction factor of cones with predicted values from Eq (4.10) in the regime $Re_\infty'>1$, in non-Newtonian media.

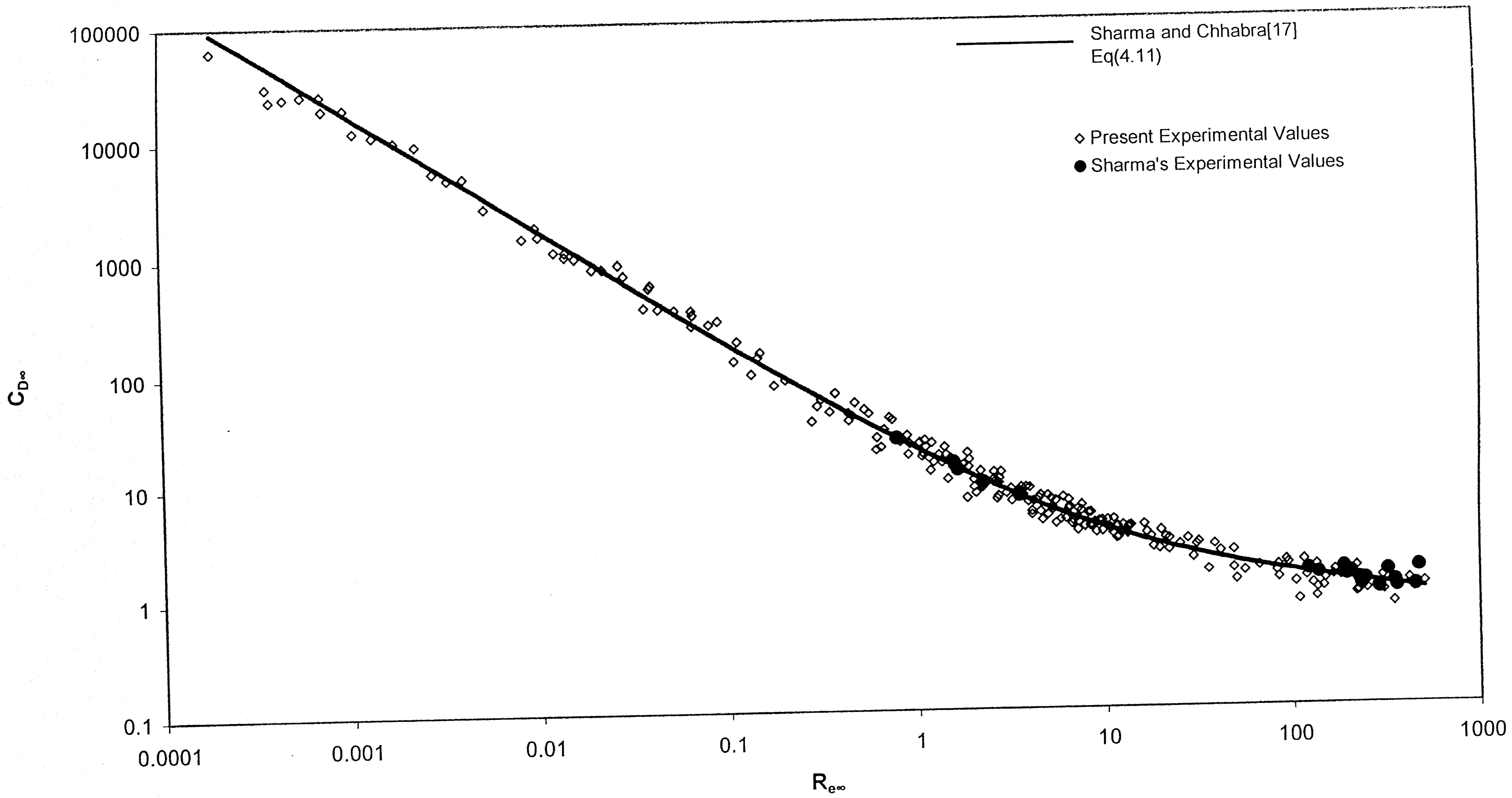


Fig 4.22 Comparison of present value of drag coefficient with predicted values of Eq (4.11).

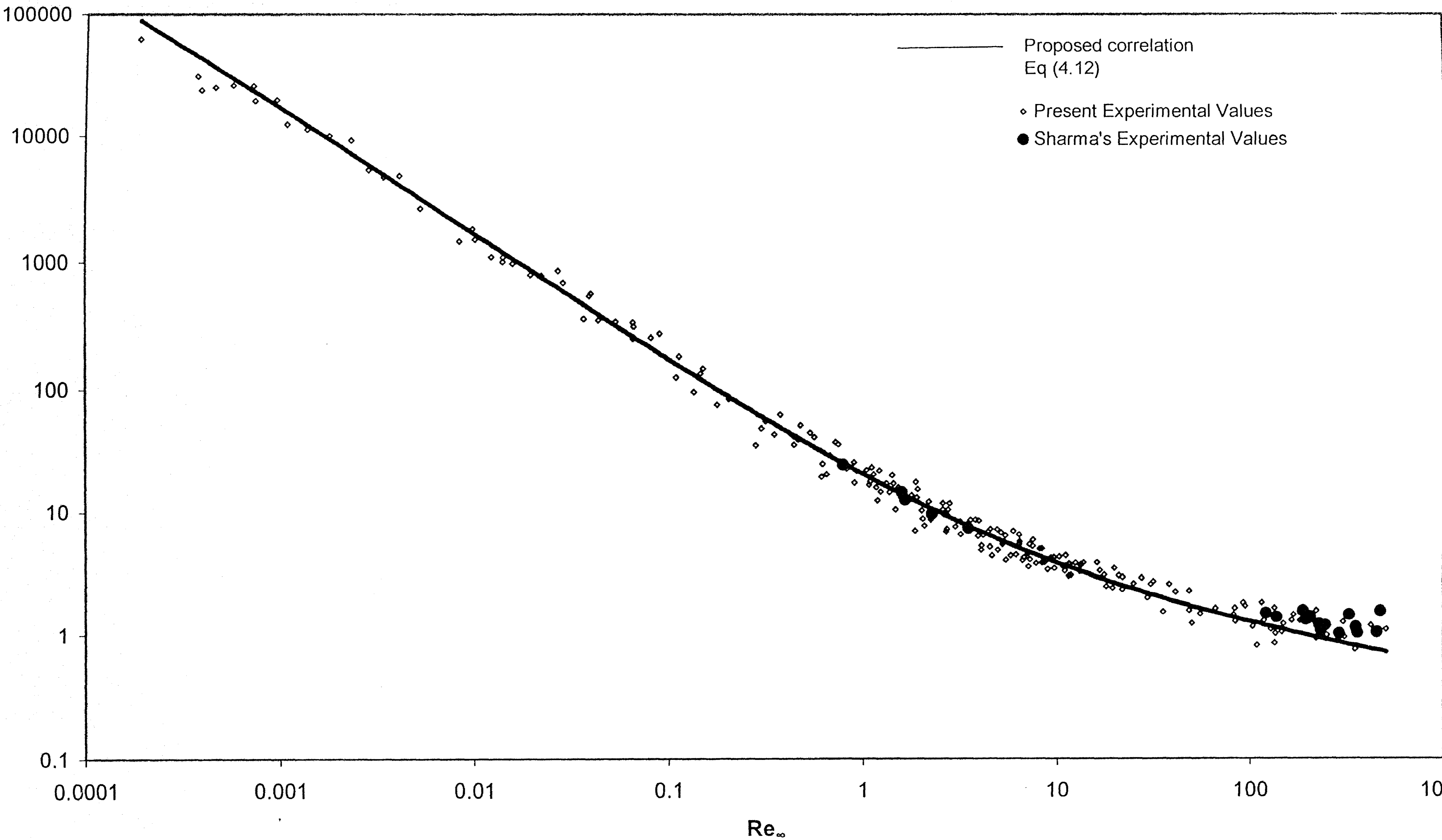


Fig4.23: Drag coefficient –Reynolds number plot for Newtonian fluids. The solid line represents the prediction of Eq. (4.12)

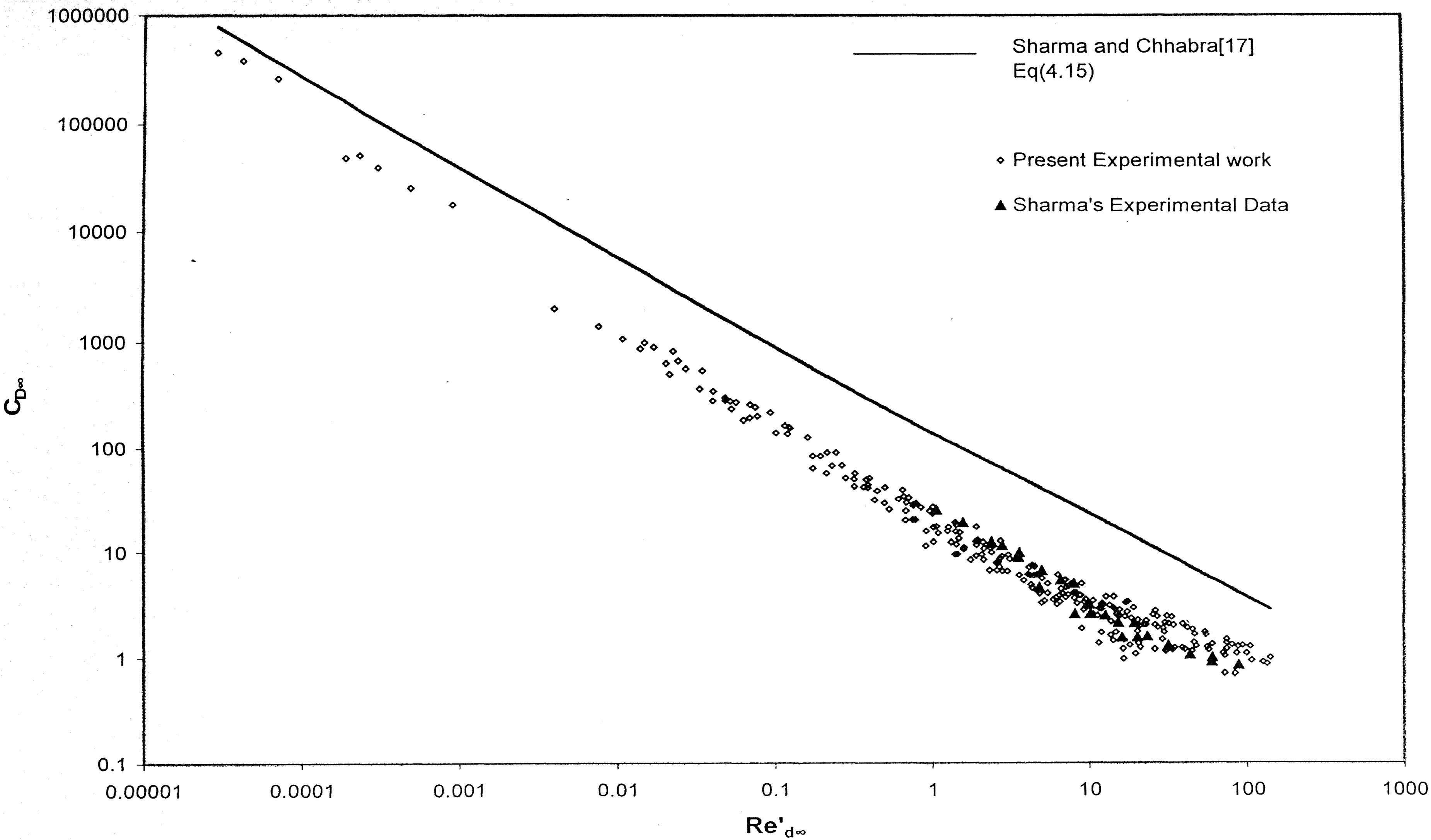


Fig 4.24: Comparison of present value of drag coefficient with predicted value of previous correlation, Eq (4.15).

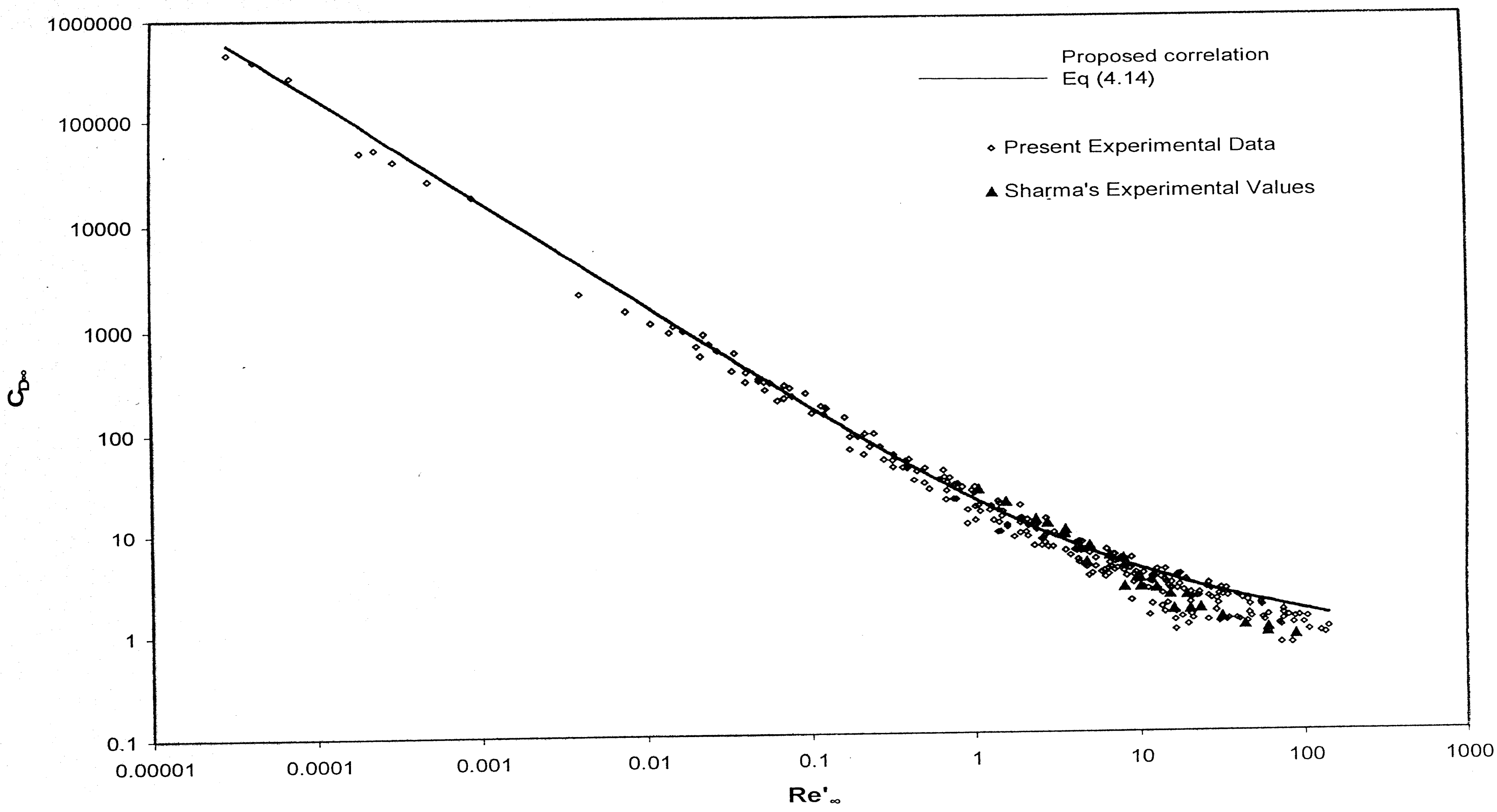
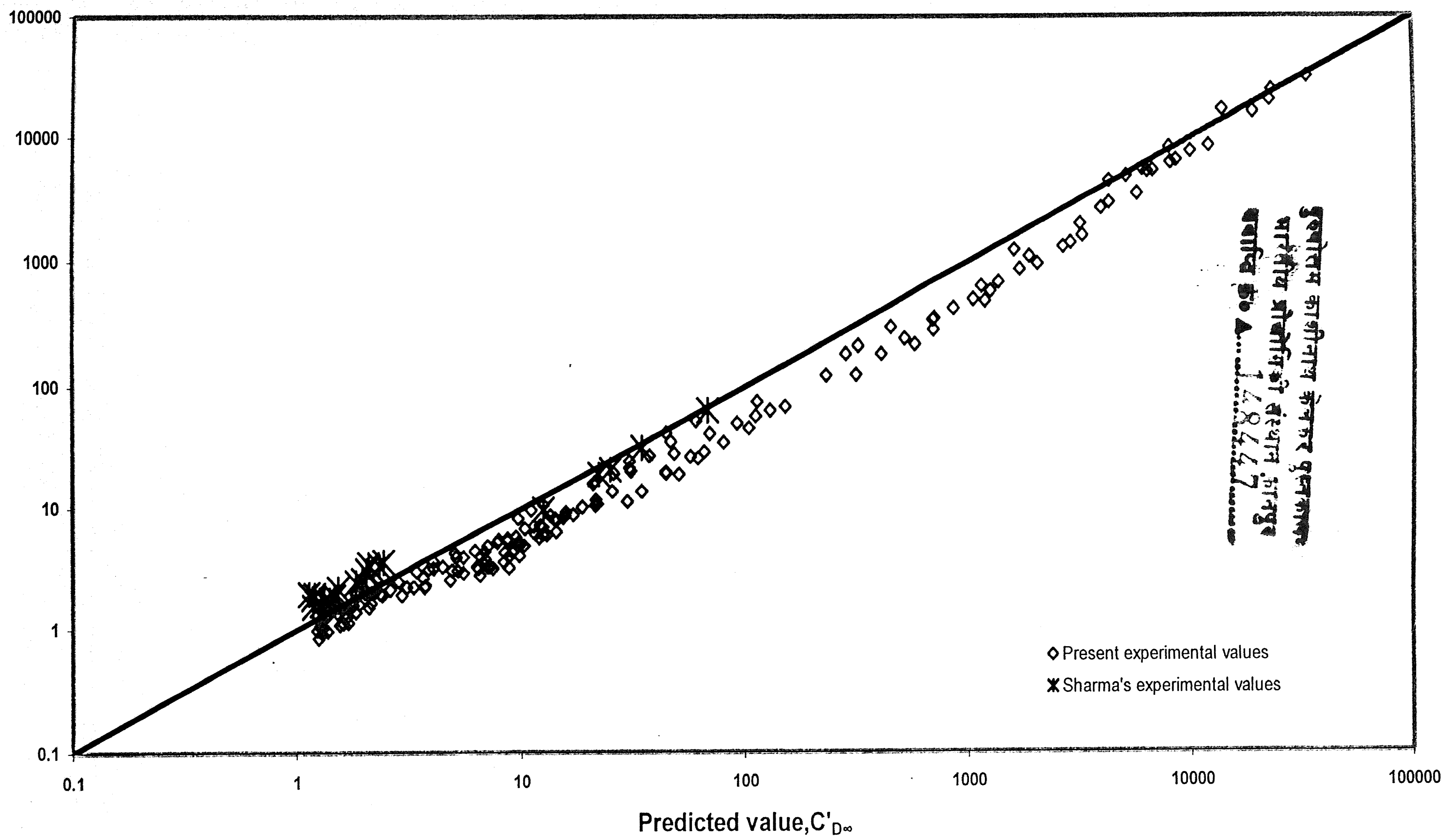
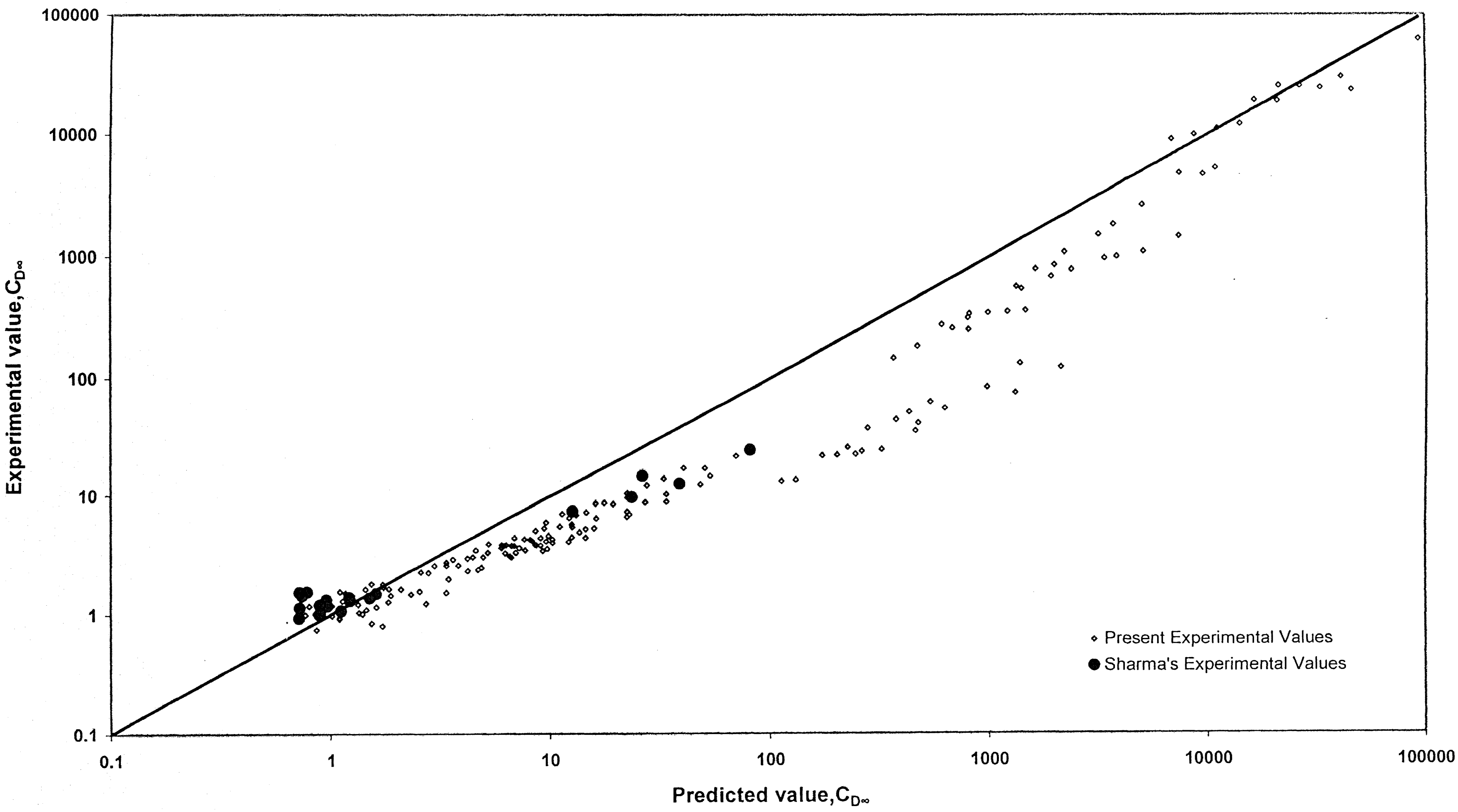


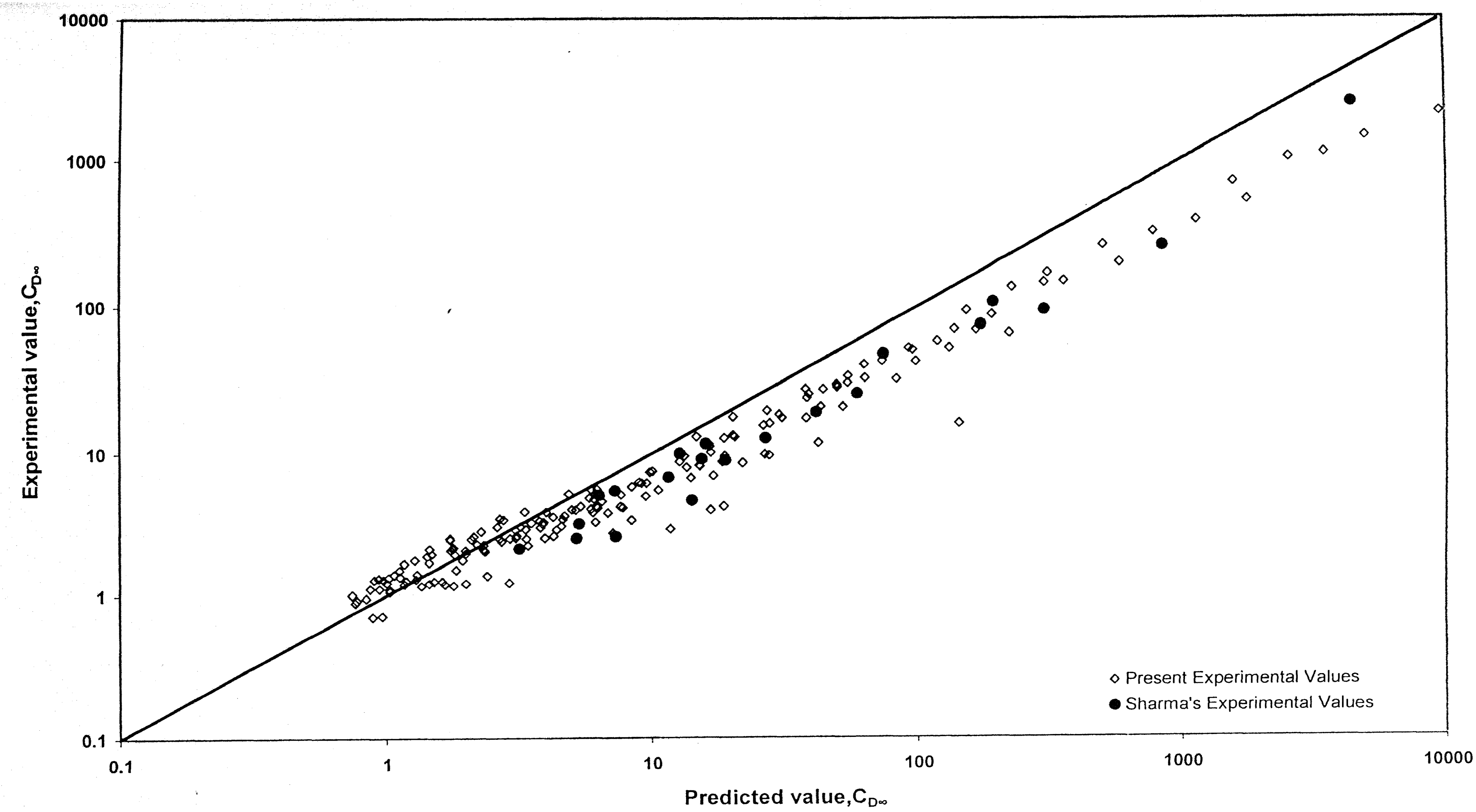
Fig 4.25: drag coefficient –Reynolds number plot for cones in non-Newtonian media for all values of Reynolds number. The solid line represents prediction of Eq 4.14



(4.26) Comparison between the experimental values of non-spherical particles and predicted values from Eq(4.17)



(4.27) Comparison between experimental values for non-spherical particles and predicted values for sphere using Eq(3.13) with the use
Re$_{eff}$ in Newtonian fluid



Fig(4.28) Comparison between experimental values for non-spherical particles and predicted values for sphere Eq(3.13) with the use of Re_{eff} in non-Newtonian fluid

Chapter 5

CONCLUSIONS AND RECOMMENDATIONS FOR FUTURE WORK

Free settling velocity of sphere and conical particles in various Newtonian and non-Newtonian media has been measured. Measurements were carried out in fall tubes of different diameters to assess the significance of possible wall effects in circular tubes.

Numerous experiments were also done with spheres in both Newtonian and non-Newtonian media to study the wall correction factors and drag values at different Reynolds numbers are studied. The close correspondence between the experimental and the literature values signify the reliability of the new experimental results for cones.

Based on the present experimental results, unified correlations have been developed for drag of cones falling in Newtonian and non-Newtonian media. Two forms of representation of the terminal velocity data (i.e. drag coefficient Reynolds number approach and velocity ratio approach) have been used in the present study. Appropriate empirical equations are presented in both Newtonian and non-Newtonian media, which provide description of data with satisfactory levels of accuracy and reliability.

From the experimental drag results, it is observed that the orientation of cone or the apex angle does not significantly affect the results with the range of conditions covered in this study, while cones with apex angle>53, fell with the apex pointing downward.

Similarly, the wall effects have been correlated using the analogy with those for spherical particles. From the experimental results, one can see that in the regime $Re_\infty<1$, the wall correction factor shows linear dependence on the diameter ratio of cone diameter to the fall tube diameter in both Newtonian and non-Newtonian media. But as the Re_∞ increases, it is observed that the wall factor is a function of diameter ratio as well as the Reynolds number.

From this analysis of wall effects, appropriate empirical equations are developed for both Newtonian and non-Newtonian media in low and intermediate Reynolds number regimes.

The present experimental results have also been compared with the other pertinent correlations available in the literature. In general there is a good overall agreement between the present results and the literature correlations.

5.1 RECOMMENDATION FOR FUTURE WORK

Clearly, considerable scope exists both for further theoretical and experimental work in this area. On the experimental front, one can extend the range of conditions notably the value of particle Reynolds number. Further experimental work can also be carried out to study the wall correction factor and drag coefficients of cone for different kinds of confining walls. The dependence of wall factor on Reynolds number, in the intermediate Reynolds number range can be further studied. Likewise, with the presently available levels of computational power, it should be possible to develop a theoretical structure to realize some of the experimental results presented herein.

Nomenclature

A	Surface area of a particle (m^2)
A_s	Specific surface area of a particle (m^{-1})
A_P	Projected area of the particle (m^2).
Ar	Archimedes Number.
$C_{D\infty}$	Drag coefficient.
$C'_{D\infty}$	Drag coefficient based on sphere volume equivalent diameter
d	Diameter of the particle (m)
d_{eff}	effective diameter (m)
d_{eq}	Diameter of the sphere having same volume as that of a non-spherical particle (m).
d_n	Diameter of the sphere having same projected area as that of the non - spherical particle (m).
D	Diameter of the fall tube (m).
f_w	Wall correction factor.
F_D	Drag force on the particle (N).
g	Acceleration due to gravity (m/s^2).
h	Height of the cone (m).
k	Power law consistency index
K'	Velocity ratio of a non-spherical particle to that of a spherical particle with same equivalent diameter.
m_P	Mass of the particle (kg).
n	Flow behavior index
Re_∞	Reynolds number based on particle equivalent diameter in Newtonian media, at unbounded terminal velocity.
Re'_∞	Reynolds number based on particle equivalent diameter in non-Newtonian media, at unbounded terminal velocity.
Re'_P	Reynolds number based on particle radius, at unbounded terminal velocity.

Re'_m	Reynolds number based on particle equivalent diameter, at the measured terminal velocity.
v	Velocity of the particle (m/s).
V_∞	Unbounded terminal velocity of the particle (m/s).
V	Volume of a particle (m^3).

Greek Symbols.

α	Apex angle of the cone.
λ	Diameter ratio of the diameter of the particle to that of fall tube.
ψ	Sphericity of the non-spherical particle.
μ	Viscosity of the Newtonian fluid (PS).
ρ_f	Density of the fluid (kg/m^3).
ρ_P	Density of the particle (kg/m^3).
τ	Shear stress (Pa).
γ	Shear rate (s^{-1}).

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APPENDICES

APPENDIX A: DRAG COEFFICIENT REYNOLDS NUMBER DATA

Newtonian media

I. SPHERES

Test Liquid 2: Glucose Solution 90%
ρ_f =1359 kg/m^3; μ=4.5 Pa.s; Temp=298 K.

Particle ID	V_∞ (m/s)	Re_∞	$C_{D\infty}$
G_B	0.080	0.526	53.091
G_DB	0.063	0.341	73.894
G_GB	0.046	0.212	104.614
G_G	0.044	0.179	127.496
G_S	0.024	0.068	286.355
G_Vs	0.019	0.052	347.137
T6	0.004	0.005	3757.632
T8	0.007	0.012	1647.124
T10	0.010	0.023	970.127
S6	0.035	0.047	398.561
S8	0.050	0.088	211.435
S10	0.075	0.175	115.034
S12	0.110	0.310	67.134

Test Liquid 3: Glucose Solution 85%
ρ_f =1349 kg/m^3; μ=1.6 Pa.s; Temp=298 K.

Particle ID	V_∞(m/s)	Re_∞	$C_{D\infty}$
G_B	0.272	6.536	5.228
G_DB	0.235	4.290	6.935
G_GB	0.180	2.732	10.261
G_G	0.170	2.437	10.747
G_S	0.110	1.020	18.392
G_Vs	0.090	0.759	23.825
T6	0.014	0.071	248.139
T8	0.026	0.175	95.896
T10	0.039	0.329	55.252
S6	0.120	0.607	34.206
S8	0.180	1.194	16.459
S10	0.240	2.121	11.334
S12	0.370	3.946	5.986

Test Liquid 4: Glucose Solution 80%
ρ_f=1318 kg/m^3; μ=0.41 Pa.s; Temp=299 K.

Particle ID	V_∞ (m/s)	Re_∞	$C_{D\infty}$
G_B	0.550	50.428	1.339
G_DB	0.416	28.974	2.349
G_GB	0.374	21.657	2.523
G_G	0.334	18.267	2.955
G_S	0.253	8.953	3.690
G_Vs	0.207	6.659	4.780
T6	0.049	0.946	21.502
T8	0.078	2.007	11.311
T10	0.108	3.474	7.648
S6	0.290	5.598	6.022
S8	0.379	9.596	3.817
S10	0.474	15.981	2.987
S12	0.631	25.679	2.116

Test Liquid 5: Glucose Solution 75%
ρ_f=1310 kg/m^3; μ=0.302 Pa.s; Temp=299 K.

Particle ID	V_∞ (m/s)	Re_∞	$C_{D\infty}$
G_B	0.600	74.175	1.140
G_DB	0.520	48.834	1.503
G_GB	0.430	33.574	1.908
G_G	0.390	28.759	2.167
G_S	0.250	11.929	3.779
G_Vs	0.190	8.242	5.674
T6	0.055	1.431	17.330
T8	0.090	3.123	8.626
T10	0.125	5.422	5.797
S6	0.290	7.548	6.065
S8	0.420	14.338	3.131
S10	0.540	24.548	2.318
S12	0.750	41.154	1.509

Test Liquid 6: Glucose Solution 70%
ρ_f=1296 kg/m^3; μ=0.15 Pa.s; Temp=298 K.

Particle ID	V_∞ (m/s)	Re_∞	$C_{D\infty}$
G_B	0.773	190.344	0.702
G_DB	0.670	125.328	0.925
G_GB	0.532	82.737	1.274

G_G	0.503	73.881	1.331
G_S	0.360	34.214	1.862
G_Vs	0.280	24.192	2.669
T6	0.096	4.977	5.842
T8	0.138	9.539	3.768
T10	0.189	16.330	2.604
S6	0.427	22.136	2.834
S8	0.552	37.534	1.836
S10	0.623	56.411	1.764
S12	0.792	86.562	1.370

Test Liquid 7: Glucose Solution 65%
ρ_f=1250 kg/m^3; μ=0.045 Pa.s; Temp=298 K.

Particle ID	V_∞ (m/s)	Re_∞	$C_{D\infty}$
G_B	0.900	718.890	0.556
G_DB	0.763	462.975	0.765
G_GB	0.629	317.321	0.978
G_G	0.615	293.021	0.955
G_S	0.425	131.026	1.433
G_Vs	0.400	112.108	1.403
T6	0.182	30.538	1.780
T8	0.224	50.224	1.560
T10	0.287	80.437	1.232
S6	0.640	107.623	1.316
S8	0.776	171.164	0.886
S10	0.890	261.413	0.824
S12	1.124	398.503	0.649

Test Liquid 9: Glycerin Solution 95%.

ρ_f=1225 kg/m^3; μ=0.309 Pa.s; Temp=300 K.

Particle ID	V_∞ (m/s)	Re_∞	$C_{D\infty}$
G_B	0.520	40.343	1.729
G_DB	0.460	27.111	2.188
G_GB	0.380	18.620	2.783
G_G	0.360	16.660	2.897
G_S	0.200	5.989	6.726
G_Vs	0.160	4.356	9.113
T6	0.030	0.490	68.347
T8	0.056	1.220	26.144
T10	0.082	2.232	15.807
S6	0.220	3.593	11.408

S8	0.300	6.427	6.642
S10	0.450	12.838	3.614
S12	0.550	18.940	3.037

Test Liquid 10: Silicone Oil
ρ_f =975 kg/m^3; μ=0.26 Pa.s; Temp=308 K.

Particle ID	V_∞ (m/s)	Re_∞	$C_{D\infty}$
G_B	0.740	81.308	1.202
G_S	0.340	19.125	2.861
G_Gb	0.480	32.040	2.169
G_DB	0.570	53.138	1.594

Test Liquid 11: Castor Oil
ρ_f =955 kg/m^3; μ=0.473 Pa.s; Temp=308 K.

Particle ID	V_∞ (m/s)	Re_∞	$C_{D\infty}$
G_B	0.700	41.844	1.389
G_S	0.275	8.416	4.519
G_GB	0.450	16.342	2.550
G_DB	0.520	26.374	1.980

II. CONES

Test Liquid 1: Glucose Solution 95%
ρ_f = 1489 kg/m^3; μ=12.2 Pa.s; Temp=302 K.

Particle ID	V_∞x10^2, (m/s)	Re_∞	$C_{D\infty}$
A1	0.394	0.0036	4250.901
A4	0.351	0.0032	4325.075
A7	0.193	0.0017	12370.446
A10	0.170	0.0015	13735.428
A13	0.162	0.0015	10874.252
A16	0.137	0.0012	14236.781
A19	0.551	0.0046	5495.777
A22	0.451	0.0041	5144.115
A25	0.413	0.0037	4914.709
A28	0.342	0.0031	8012.333
A31	0.310	0.0028	8261.267
A34	0.283	0.0025	7594.781
B1	2.450	0.0223	462.738
B4	1.912	0.0173	640.700
B7	1.612	0.0147	883.206

B10	1.506	0.0137	1062.334
B13	0.602	0.0055	2736.511
B16	0.881	0.0080	1542.206
B19	0.752	0.0068	2796.800

Test Liquid 2: Glucose Solution 90%
ρ_f =1359 kg/m^3; μ=6.1 Pa.s; Temp=298 K.

Particle ID	$V_\infty x10^2$, (m/s)	Re_∞	$C_{D\infty}$
A1	1.40	0.025	356.979
A4	1.25	0.021	366.943
A7	0.70	0.009	986.245
A10	0.65	0.008	1016.721
A13	0.52	0.007	1114.092
A16	0.42	0.005	1476.007
A19	2.30	0.052	281.062
A22	1.81	0.038	344.086
A25	1.60	0.031	349.232
A28	1.35	0.022	549.968
A31	1.00	0.015	859.129
A34	0.90	0.013	795.490
B1	6.00	0.087	148.397
B4	4.90	0.066	185.281
B7	4.10	0.047	261.943
B10	3.80	0.038	318.374
B13	1.65	0.016	695.974
B16	3.00	0.038	255.227
B19	2.30	0.023	571.992

Test Liquid 3: Glucose Solution 85%
ρ_f =1349 kg/m^3; μ=1.6 Pa.s; Temp=298 K.

Particle ID	$V_\infty x10^2$, (m/s)	Re_∞	$C_{D\infty}$
A1	5.30	0.358	25.295
A4	4.00	0.254	36.391
A7	2.40	0.118	85.202
A10	1.80	0.084	134.641
A13	2.00	0.103	76.482
A16	1.45	0.063	125.760
A19	8.20	0.700	22.456
A22	6.60	0.519	26.280
A25	6.10	0.441	24.400
A28	4.40	0.275	52.577

A31	3.70	0.216	63.731
A34	3.40	0.182	56.605
B1	20.00	1.095	13.472
B4	18.00	0.911	13.850
B7	14.00	0.602	22.662
B10	11.00	0.417	38.326
B13	6.70	0.253	42.578
B16	10.00	0.475	23.171
B19	8.20	0.308	45.394

Test Liquid 4: Glucose Solution 80%
ρ_f=1318 kg/m^3; μ=0.41 Pa.s; Temp=299 K.

Particle ID	$V_\infty x10^2$, (m/s)	Re_∞	$C_{D\infty}$
A1	13.00	3.349	4.410
A4	10.80	2.618	5.236
A7	8.40	1.569	7.295
A10	7.23	1.291	8.753
A13	6.00	1.174	8.913
A16	4.30	0.714	14.999
A19	20.50	6.673	3.769
A22	17.00	5.100	4.155
A25	15.20	4.193	4.122
A28	12.50	2.984	6.833
A31	10.30	2.296	8.626
A34	9.00	1.834	8.473
B1	38.00	7.931	3.835
B4	35.00	6.752	3.765
B7	32.80	5.377	4.243
B10	30.00	4.331	5.295
B13	20.00	2.882	4.911
B16	25.00	4.523	3.810
B19	22.00	3.150	6.481

Test Liquid 5: Glucose Solution 75%
ρ_f=1310 kg/m^3; μ=0.302 Pa.s; Temp=299 K.

Particle ID	$V_\infty x10^2$, (m/s)	Re_∞	$C_{D\infty}$
A1	14.00	4.867	14.00
A4	12.00	3.925	12.00
A7	9.00	2.268	9.00
A10	6.60	1.591	6.60
A13	7.00	1.849	7.00

A16	5.20	1.165	5.20
A19	22.00	9.663	22.00
A22	17.80	7.205	17.80
A25	15.00	5.584	15.00
A28	13.50	4.348	13.50
A31	11.50	3.459	11.50
A34	11.00	3.025	11.00
B1	43.00	12.111	43.00
B4	39.00	10.152	39.00
B7	35.00	7.742	35.00
B10	33.00	6.429	33.00
B13	19.00	3.694	19.00
B16	28.00	6.836	28.00
B19	25.00	4.831	25.00
N1	3.00	1.549	3.00
N4	2.00	0.689	2.00

Test Liquid 6: Glucose Solution 70%
ρ_f=1296 kg/m^3; μ=0.15 Pa.s; Temp=298 K.

Particle ID	$V_\infty x10^2$, (m/s)	Re_∞	$C_{D\infty}$
A1	18.20	12.601	2.327
A4	16.00	10.425	2.468
A7	13.30	6.676	3.010
A10	11.70	5.617	3.458
A13	9.87	5.192	3.407
A16	8.00	3.569	4.483
A19	25.30	22.135	2.559
A22	22.00	17.737	2.566
A25	19.50	14.458	2.591
A28	17.90	11.483	3.447
A31	15.60	9.345	3.890
A34	14.00	7.669	3.622
B1	50.00	28.049	2.259
B4	46.00	23.850	2.223
B7	41.50	18.284	2.703
B10	41.00	15.910	2.892
B13	29.00	11.230	2.382
B16	35.00	17.019	1.983
B19	33.00	12.701	2.938

Test Liquid 7: Glucose Solution 65%
ρ_f=1250 kg/m^3; μ=0.045 Pa.s; Temp=298 K.

Particle ID	$V_\infty x10^2$, (m/s)	Re_∞	$C_{D\infty}$
A1	26.80	60.192	1.152
A4	23.10	48.823	1.271
A7	19.70	32.076	1.473
A10	18.00	28.032	1.568
A13	17.00	29.010	1.233
A16	14.20	20.549	1.527
A19	37.00	105.007	1.284
A22	33.15	86.699	1.213
A25	28.60	68.788	1.293
A28	26.40	54.937	1.701
A31	24.90	48.388	1.639
A34	21.60	38.384	1.633
B1	67.50	122.831	1.293
B4	58.20	97.883	1.448
B7	54.50	77.889	1.635
B10	53.00	66.717	1.805
B13	38.00	47.734	1.447
B16	50.00	78.869	1.013
B19	43.00	53.685	1.805

Test Liquid 8: Glucose Solution 60%
ρ_f=1219 kg/m^3; μ=0.02 Pa.s; Temp=298K.

Particle ID	$V_\infty x10^2$, (m/s)	Re_∞	$C_{D\infty}$
A1	26.80	60.192	1.152
A4	23.10	48.823	1.271
A7	19.70	32.076	1.473
A10	18.00	28.032	1.568
A13	17.00	29.010	1.233
A16	14.20	20.549	1.527
A19	37.00	105.007	1.284
A22	33.15	86.699	1.213
A25	28.60	68.788	1.293
A28	26.40	54.937	1.701
A31	24.90	48.388	1.639
A34	21.60	38.384	1.633
B1	67.50	122.831	1.293
B4	58.20	97.883	1.448
B7	54.50	77.889	1.635
B10	53.00	66.717	1.805
B13	38.00	47.734	1.447
B16	50.00	78.869	1.013

B19	43.00	53.685	1.805

Test Liquid 9: Glycerin Solution 95%.

ρ_f=1225 kg/m^3; μ=0.309 Pa.s; Temp=300 K.

Particle ID	$V_\infty x10^2$, (m/s)	Re_∞	$C_{D\infty}$
A1	13.50	4.290	4.719
A4	11.00	3.290	5.824
A7	6.00	1.382	16.500
A10	5.00	1.102	21.120
A13	4.50	1.087	18.286
A16	3.50	0.717	26.126
A19	21.50	8.634	3.954
A22	18.50	6.846	4.049
A25	16.00	5.445	4.293
A28	12.25	3.607	8.210
A31	10.50	2.887	9.578
A34	8.50	2.137	10.962
B1	43.00	11.072	3.262
B4	39.00	9.281	3.302
B7	36.00	7.280	3.836
B10	33.60	5.985	4.597
B13	22.00	3.910	4.420
B16	27.00	6.026	3.557
B19	25.00	4.416	5.466
N1	3.90	1.842	12.341
N4	2.80	0.881	19.475

Test Liquid 10: Silicone Oil

ρ_f=975 kg/m^3; μ=0.26 Pa.s; Temp=308 K.

Particle ID	$V_\infty x10^2$, (m/s)	Re_∞	$C_{D\infty}$
P1	7.410	3.882	6.628
P4	8.835	5.104	6.781
P7	6.020	3.044	9.230
P10	5.780	2.780	8.841
P13	4.614	2.052	10.608
P16	3.381	1.318	13.062
P19	1.966	0.634	21.668
P22	5.055	2.045	14.944
P25	4.633	1.714	13.742
P28	3.201	1.090	22.051
P31	2.517	0.751	24.078

P34	1.407	0.348	44.000
n1	14.011	7.440	5.103
n6	7.801	2.900	11.100
b1	42.200	10.120	4.436
b4	35.501	7.979	5.171
b7	32.100	6.118	6.299
b10	30.020	5.965	7.483
b14	23.730	4.076	4.941
b17	22.775	4.155	6.501
b19	22.550	3.780	8.755
bA	17.320	2.580	9.826

Test Liquid 11: Castor Oil
ρ_f =955 kg/m^3; μ=0.473 Pa.s; Temp=308 K.

Particle ID	$V_\infty x10^2$, (m/s)	Re_∞	$C_{D\infty}$
P1	6.010	1.695	11.250
P4	6.880	2.124	12.673
P7	5.321	1.447	13.200
P10	4.804	1.243	14.306
P13	3.512	0.841	20.447
P16	2.796	0.567	22.842
P19	1.337	0.226	54.965
P22	3.607	0.785	32.815
P25	3.002	0.598	36.527
P28	2.250	0.404	52.062
P31	1.661	0.267	61.431
P34	0.955	0.127	106.633
N1	10.201	2.919	8.336
N6	6.110	1.201	19.896
B1	30.190	3.892	8.899
B4	28.597	3.449	8.211
B7	25.400	2.574	10.563
B10	24.636	2.569	11.966
B13	14.008	1.296	14.494
B16	19.551	1.868	9.540
B19	16.534	1.492	16.663
BA	12.814	1.028	18.371

Non Newtonian Media

I. SPHERES

Test Liquid 14: CMC 0.75%
Density, ρ_f =1000 kg/m^3; n=0.591; k=0.529(P.S^n); Temp=291K

Particle ID	V_∞ (m/s)	Re_∞'	$C_{D\infty}$	n	k(P.S^n)
S6	0.87	74.425	0.099	0.591	0.529
S8	1	107.911	0.077	0.591	0.529
S10	1.35	195.082	0.040	0.591	0.529
S12	1.49	250.553	0.053	0.591	0.529
G_S	0.45	46.437	0.169	0.591	0.529
G_G	0.73	113.860	0.084	0.591	0.529
G_GB	0.76	129.822	0.070	0.591	0.529
G_DB	1.12	247.679	0.042	0.591	0.529
G_B	1.3	341.001	0.036	0.591	0.529
T6	0.15	6.347	0.490	0.591	0.529
T8	0.22	12.905	0.303	0.591	0.529
T10	0.295	22.260	0.219	0.591	0.529

Test Liquid 15: CMC 0.6%
Density, ρ_f =1000 kg/m^3; n=0.623; k=0.292 (P.S^n); Temp=291K

Particle ID	V_∞ (m/s)	Re_∞'	$C_{D\infty}$	n	k(P.S^n)
S6	1.07	153.001	0.065	0.623	0.292
S8	1.27	233.029	0.048	0.623	0.292
S10	1.42	324.820	0.037	0.623	0.292
S12	1.52	401.090	0.051	0.623	0.292
G_S	0.65	124.668	0.081	0.623	0.292
G_G	0.9	244.841	0.055	0.623	0.292
G_GB	0.95	285.293	0.045	0.623	0.292
G_DB	1.12	397.502	0.042	0.623	0.292
G_B	1.35	577.144	0.034	0.623	0.292
T6	0.22	17.595	0.228	0.623	0.292
T8	0.345	39.112	0.123	0.623	0.292
T10	0.45	64.802	0.094	0.623	0.292

Test Liquid 16: CMC 0.5%
Density, ρ_f =1000 kg/m^3; n=0.617; k=0.261(P.S^n); Temp=292K

Particle ID	V_∞ (m/s)	Re_∞'	$C_{D\infty}$	n	$k(P.S^n)$
S6	1.22	211.864	0.050	0.617	0.261
S8	1.4	307.731	0.039	0.617	0.261
S10	1.6	441.666	0.029	0.617	0.261
S12	1.77	570.367	0.038	0.617	0.261
G_S	0.55	113.386	0.113	0.617	0.261
G_G	0.91	284.834	0.054	0.617	0.261
G_GB	1	350.741	0.040	0.617	0.261
G_DB	1.2	500.793	0.036	0.617	0.261
G_B	1.3	627.308	0.036	0.617	0.261
T6	0.29	29.488	0.131	0.617	0.261
T8	0.39	53.050	0.097	0.617	0.261
T10	0.538	95.000	0.066	0.617	0.261

Test Liquid 17: CMC 0.4%
Density, ρ_f=1000 kg/m^3; n=0.669; k=0.231($P.S^n$); Temp=293K

Particle ID	V_∞ (m/s)	Re_∞'	$C_{D\infty}$	n	$k(P.S^n)$
S6	1.18	173.665	0.054	0.669	0.230
S8	1.13	199.938	0.060	0.669	0.230
S10	1.54	365.637	0.031	0.669	0.230
S12	2.21	670.669	0.024	0.669	0.230
G_S	0.55	105.525	0.113	0.669	0.230
G_G	0.73	196.254	0.084	0.669	0.230
G_GB	0.76	225.271	0.070	0.669	0.230
G_DB	0.91	320.475	0.063	0.669	0.230
G_B	1.1	467.049	0.051	0.669	0.230
T6	0.245	21.803	0.184	0.669	0.230
T8	0.335	40.082	0.131	0.669	0.230
T10	0.468	72.617	0.087	0.669	0.230

Test Liquid 18: Methocel 1.2%
Density, ρ_f=1000 kg/m^3; n=0.698; k=2.069($P.S^n$); Temp=296K

Particle ID	V_∞ (m/s)	Re_∞'	$C_{D\infty}$	n	$k(P.S^n)$
S6	8.70E-03	0.027731	985.4376	0.698	2.069
S8	1.10E-02	0.046294	634.4216	0.698	2.069
S10	1.50E-02	0.084669	327.4069	0.698	2.069
S12	2.90E-02	0.227793	140.2735	0.698	2.069
S14	3.50E-02	0.303714	102.0631	0.698	2.069

G_S	6.00E-03	0.029334	953.3732	0.698	2.069
G_G	9.50E-03	0.068801	496.3128	0.698	2.069
G_GB	1.10E-02	0.090924	331.9855	0.698	2.069
G_DB	2.08E-02	0.234421	121.0717	0.698	2.069
G_B	3.12E-02	0.451877	63.46349	0.698	2.069

Test Liquid 19: Methocel 1.0%
Density, ρ_f =1000 kg/m^3; n=0.720; k=1.074(P.S^n); Temp=296K

Particle ID	V_∞ (m/s)	Re_∞'	$C_{D\infty}$	n	k(P.S^n)
S6	1.75E-02	0.130	243.552	0.720	1.074
S8	2.80E-02	0.293	97.915	0.720	1.074
S10	3.80E-02	0.532	51.016	0.720	1.074
S12	6.40E-02	1.188	28.801	0.720	1.074
G_S	1.30E-02	0.155	203.085	0.720	1.074
G_G	3.14E-02	0.621	45.459	0.720	1.074
G_GB	3.25E-02	0.711	38.031	0.720	1.074
G_DB	4.00E-02	1.047	32.738	0.720	1.074
G_B	5.50E-02	1.799	20.383	0.720	1.074

Test Liquid 20: Methocel 0.75%
Density, ρ_f =1000 kg/m^3; n=0.663; k=1.003(P.S^n); Temp=288K

Particle ID	V_∞ (m/s)	Re_∞'	$C_{D\infty}$	n	k(P.S^n)
S6	0.5	13.128	0.298	0.662	1.002
S8	0.6	20.391	0.213	0.662	1.002
S10	0.7	30.294	0.150	0.662	1.002
S12	0.81	41.713	0.180	0.662	1.002
G_S	0.35	13.594	0.280	0.662	1.002
G_G	0.55	31.673	0.148	0.662	1.002
G_GB	0.59	37.819	0.115	0.662	1.002
G_DB	0.76	59.332	0.091	0.662	1.002
G_B	1.21	125.003	0.042	0.662	1.002

Test Liquid 20: Methocel 0.65%
Density, ρ_f =1000 kg/m^3; n=0.689; k=0.662(P.S^n); Temp=289K

Particle ID	V_∞ (m/s)	Re_∞'	$C_{D\infty}$	n	k(P.S^n)
S6	0.61	23.012	0.200	0.688	0.661
S8	0.89	46.326	0.097	0.688	0.661
S10	1.18	81.680	0.053	0.688	0.661
S12	1.57	135.225	0.048	0.688	0.661
G_S	0.5	30.185	0.137	0.688	0.661
G_G	0.65	54.713	0.106	0.688	0.661
G_GB	0.6	53.718	0.112	0.688	0.661
G_DB	0.8	87.983	0.082	0.688	0.661
G_B	0.95	125.259	0.068	0.688	0.661
T6	0.1	2.184	1.102	0.688	0.661
T8	0.16	4.931	0.574	0.688	0.661
T10	0.225	8.992	0.376	0.688	0.661

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Test Liquid 12: CMC 1.5%
Density, ρ_f =1000 kg/m^3; n=0.403; k=6.883(P.S^n); Temp=300K

Particle ID	V_∞x10^2 (m/s)	Re_∞'	$C_{D\infty}$	n	k(P.S^n)
P1	0.252	1.85E-03	4924.495	0.403	6.883
P4	0.275	2.20E-03	5982.953	0.403	6.883
P7	0.248	1.74E-03	4500.605	0.403	6.883
P10	0.235	1.61E-03	4608.336	0.403	6.883
P13	0.159	8.27E-04	7649.378	0.403	6.883
P22	0.148	7.08E-04	14815.749	0.403	6.883
P25	0.13	5.57E-04	15026.675	0.403	6.883
P28	0.11	4.11E-04	16682.676	0.403	6.883
P31	0.08	2.34E-04	20958.570	0.403	6.883
A1	1.72	3.16E-02	421.652	0.403	6.883
A4	1.38	2.17E-02	536.750	0.403	6.883
A7	0.71	6.74E-03	1709.135	0.403	6.883
A10	0.62	5.34E-03	1494.233	0.403	6.883
A19	3.25	9.58E-02	236.197	0.403	6.883
A22	2.79	7.26E-02	278.215	0.403	6.883
A25	2.22	4.88E-02	323.415	0.403	6.883
A28	1.5	2.45E-02	709.115	0.403	6.883

A31	1	1.25E-02	1308.318	0.403	6.883
A34	0.84	9.14E-03	1401.950	0.403	6.883
B1	17	1.12E+00	26.451	0.403	6.883
B4	15.3	9.22E-01	27.046	0.403	6.883
B7	10.5	4.73E-01	56.690	0.403	6.883
B10	9.75	4.27E-01	68.854	0.403	6.883
B16	9.4	3.88E-01	37.012	0.403	6.883
B19	6	1.84E-01	118.412	0.403	6.883

Test Liquid 13: CMC 1.3%
Density, ρ_f =1000 kg/m^3; n=0.497; k=2.166(P.S^n); Temp=291K

Particle ID	$V_\infty x10^2$ (m/s)	Re_∞'	CD_∞	n	k(P.S^n)
P1	1.04	0.058	289.132	0.497	2.166
P4	1.15	0.071	342.125	0.497	2.166
P7	0.95	0.049	306.709	0.497	2.166
P10	1.01	0.054	249.481	0.497	2.166
P13	0.75	0.033	343.794	0.497	2.166
P22	0.61	0.023	872.142	0.497	2.166
P25	0.55	0.019	839.507	0.497	2.166
P28	0.47	0.014	913.809	0.497	2.166
A1	5.6	0.550	39.777	0.497	2.166
A4	4.75	0.417	45.305	0.497	2.166
A7	2.6	0.148	127.452	0.497	2.166
A10	2.1	0.105	130.246	0.497	2.166
A19	9.5	1.367	27.644	0.497	2.166
A22	8.4	1.091	30.692	0.497	2.166
A25	6.8	0.762	34.471	0.497	2.166
A28	5.25	0.479	57.887	0.497	2.166
A31	4.1	0.320	77.830	0.497	2.166
A34	3.25	0.216	93.654	0.497	2.166
B1	52.5	14.282	2.773	0.497	2.166
B4	48.5	12.231	2.692	0.497	2.166
B7	44.75	9.987	3.121	0.497	2.166
B10	41	8.917	3.894	0.497	2.166
B16	35	6.725	2.670	0.497	2.166
B19	25	3.903	6.821	0.497	2.166

Test Liquid 14: CMC 0.75%
Density, ρ_f =1000 kg/m^3; n=0.591; k=0.529(P.S^n); Temp=291K

Particle ID	$V_\infty x10^2$ (m/s)	Re_∞'	$C_{D\infty}$	n	$k(P.S^n)$
P1	7.4	3.885	5.562	0.591	0.529
P4	7.95	4.544	7.159	0.591	0.529
P7	6.6	3.152	6.355	0.591	0.529
P10	6.8	3.326	5.504	0.591	0.529
P13	6.4	2.869	4.721	0.591	0.529
P22	5.4	2.124	11.135	0.591	0.529
P25	4.7	1.665	11.496	0.591	0.529
P28	3.6	1.082	15.576	0.591	0.529
A1	25	15.435	1.996	0.591	0.529
A4	22.5	12.857	2.019	0.591	0.529
A7	18	8.024	2.659	0.591	0.529
A10	15	6.059	2.553	0.591	0.529
A19	43	38.062	1.349	0.591	0.529
A22	35.5	27.671	1.718	0.591	0.529
A25	30.5	21.275	1.713	0.591	0.529
A28	27.5	16.816	2.110	0.591	0.529
A31	24.8	13.994	2.127	0.591	0.529
A34	20.5	10.160	2.354	0.591	0.529
B1	87.5	79.446	0.998	0.591	0.529
B4	75	61.261	1.126	0.591	0.529
B7	66	46.424	1.435	0.591	0.529
B10	56.5	38.111	2.050	0.591	0.529
B16	51	31.298	1.257	0.591	0.529
B19	47.5	27.048	1.889	0.591	0.529

Test Liquid 15: CMC 0.6%
Density, ρ_f =1000 kg/m^3; n=0.623; k=0.292 ($P.S^n$); Temp=291K

Particle ID	$V_\infty x10^2$ (m/s)	Re_∞'	$C_{D\infty}$	n	$k(P.S^n)$
P1	14.3	16.544	1.489	0.623	0.292
P4	15.8	20.124	1.812	0.623	0.292
P7	12.9	13.647	1.663	0.623	0.292
P10	13.1	14.112	1.483	0.623	0.292
P13	11.8	11.442	1.389	0.623	0.292
P22	9.8	8.308	3.381	0.623	0.292
P25	8.5	6.491	3.515	0.623	0.292
P28	7.5	5.153	3.589	0.623	0.292
A1	31.5	34.467	1.257	0.623	0.292
A4	29.5	30.373	1.175	0.623	0.292

A7	25	20.493	1.379	0.623	0.292
A10	21.6	16.337	1.231	0.623	0.292
A19	48.5	72.266	1.061	0.623	0.292
A22	42.5	57.230	1.199	0.623	0.292
A25	37	44.906	1.164	0.623	0.292
A28	35.6	38.760	1.259	0.623	0.292
A31	33	33.540	1.201	0.623	0.292
A34	28.5	25.950	1.218	0.623	0.292
B1	93	133.990	0.884	0.623	0.292
B4	81.5	106.797	0.953	0.623	0.292
B7	75	85.973	1.111	0.623	0.292
B10	70	79.985	1.336	0.623	0.292
B16	67.5	71.972	0.718	0.623	0.292
B19	58	55.652	1.267	0.623	0.292

Test Liquid 16: CMC 0.5%
Density, ρ_f =1000 kg/m^3; n=0.617; k=0.261(P.S^n); Temp=292K

Particle ID	$V_\infty x10^2$ (m/s)	Re_∞'	CD_∞	n	k(P.S^n)
P1	15.5	20.969	1.268	0.617	0.261
P4	19.5	30.527	1.190	0.617	0.261
P7	14.4	18.013	1.335	0.617	0.261
P10	15.2	19.651	1.102	0.617	0.261
P13	14	16.431	0.987	0.617	0.261
P22	13.5	14.662	1.782	0.617	0.261
P25	12	11.847	1.764	0.617	0.261
P28	10.2	8.930	1.940	0.617	0.261
A1	37.5	50.152	0.887	0.617	0.261
A4	35.9	45.558	0.793	0.617	0.261
A7	27.5	26.745	1.139	0.617	0.261
A10	25.5	23.496	0.883	0.617	0.261
A19	54.5	97.198	0.840	0.617	0.261
A22	44	68.704	1.119	0.617	0.261
A25	42.5	62.221	0.882	0.617	0.261
A28	41	53.939	0.949	0.617	0.261
A31	36.1	43.466	1.004	0.617	0.261
A34	30	31.874	1.099	0.617	0.261
B1	87	140.788	1.010	0.617	0.261
B4	83	126.160	0.919	0.617	0.261
B7	75	99.079	1.111	0.617	0.261

B10	70.5	93.030	1.317	0.617	0.261
B16	68	83.767	0.707	0.617	0.261
B19	62	70.281	1.109	0.617	0.261

Test Liquid 17: CMC 0.4%
Density, ρ_f =1000 kg/m^3; n=0.669; k=0.231(P.S^n); Temp=293K

Particle ID	V_∞x10^2 (m/s)	Re_∞'	CD_∞	n	k(P.S^n)
P1	15.8	21.487	1.220	0.669	0.231
P4	19.5	30.276	1.190	0.669	0.231
P7	14.2	17.655	1.373	0.669	0.231
P10	15	19.244	1.131	0.669	0.231
P13	12.5	14.067	1.238	0.669	0.231
P22	12.8	13.549	1.982	0.669	0.231
P25	12	11.774	1.764	0.669	0.231
P28	9.7	8.331	2.145	0.669	0.231
A1	36	43.959	0.963	0.669	0.231
A4	33.5	38.424	0.911	0.669	0.231
A7	27	24.137	1.182	0.669	0.231
A10	25.2	21.429	0.904	0.669	0.231
A19	52	83.886	0.923	0.669	0.231
A22	44.5	64.519	1.094	0.669	0.231
A25	40.5	53.846	0.972	0.669	0.231
A28	39.8	47.553	1.007	0.669	0.231
A31	35	38.383	1.068	0.669	0.231
A34	32	32.124	0.966	0.669	0.231
B1	94	136.627	0.865	0.669	0.231
B4	83	110.303	0.919	0.669	0.231
B7	75	86.339	1.111	0.669	0.231
B10	73	85.357	1.228	0.669	0.231
B16	67.5	72.456	0.718	0.669	0.231
B19	62.5	62.099	1.091	0.669	0.231

Test Liquid 18: Methocel 1.2%
Density, ρ_f =1000 kg/m^3; n=0.698; k=2.069(P.S^n); Temp=296K

Particle ID	V_∞x10^2 (m/s)	Re_∞'	CD_∞	n	k(P.S^n)
P1	0.98	0.060	325.620	0.698	2.069
P4	1.2	0.083	314.209	0.698	2.069
P7	0.82	0.045	411.667	0.698	2.069

P10	0.92	0.053	300.680	0.698	2.069
P13	0.8	0.041	302.162	0.698	2.069
P22	0.6	0.026	901.456	0.698	2.069
P25	0.45	0.017	1254.078	0.698	2.069
P28	0.55	0.021	667.307	0.698	2.069
P31	0.33	0.010	1231.725	0.698	2.069
A1	3.9	0.243	82.013	0.698	2.069
A4	3.4	0.195	88.424	0.698	2.069
A7	2.4	0.103	149.579	0.698	2.069
A10	1.7	0.064	198.749	0.698	2.069
A19	6.6	0.568	57.273	0.698	2.069
A22	5	0.373	86.626	0.698	2.069
A25	4.8	0.334	69.180	0.698	2.069
A28	3.5	0.199	130.246	0.698	2.069
A31	3.1	0.163	136.141	0.698	2.069
A34	2.6	0.122	146.334	0.698	2.069
B1	19	1.644	21.175	0.698	2.069
B4	16	1.250	24.731	0.698	2.069
B7	12	0.766	43.403	0.698	2.069
B10	14	0.961	33.395	0.698	2.069
B16	8.5	0.471	45.265	0.698	2.069
B19	7.8	0.399	70.066	0.698	2.069

Test Liquid 19: Methocel 1.0%
Density, ρ_f=1000 kg/m^3; n=0.720; k=1.074(P.S^n); Temp=296K

Particle ID	V_∞x10^2 (m/s)	Re_∞'	CD_∞	n	k(P.S^n)
P1	2.8	0.446	39.888	0.720	1.074
P4	3.6	0.658	34.912	0.720	1.074
P7	2.52	0.367	43.589	0.720	1.074
P10	2.22	0.317	51.639	0.720	1.074
P13	1.48	0.175	88.287	0.720	1.074
P22	1.85	0.216	94.821	0.720	1.074
P25	1.2	0.117	176.355	0.720	1.074
P28	0.85	0.070	279.392	0.720	1.074
P31	0.6	0.041	372.597	0.720	1.074
A1	7	0.957	25.457	0.720	1.074
A4	6	0.754	28.394	0.720	1.074
A7	4.1	0.382	51.254	0.720	1.074
A10	3.3	0.281	52.744	0.720	1.074

A19	13.8	2.702	13.100	0.720	1.074
A22	11	1.904	17.898	0.720	1.074
A25	9	1.387	19.678	0.720	1.074
A28	7.6	1.002	27.623	0.720	1.074
A31	6.9	0.845	27.480	0.720	1.074
A34	4.8	0.499	42.935	0.720	1.074
B1	42.5	8.259	4.232	0.720	1.074
B4	37	6.566	4.625	0.720	1.074
B7	32.7	4.979	5.845	0.720	1.074
B10	29.5	4.481	7.521	0.720	1.074
B16	20.22	2.591	7.999	0.720	1.074
B19	19.5	2.339	11.211	0.720	1.074

Test Liquid 20: Methocel 0.75%
Density, ρ_f =1000 kg/m^3; n=0.663; k=1.003(P.S^n); Temp=288K

Particle ID	$V_\infty x10^2$ (m/s)	Re_∞'	CD_∞	n	k(P.S^n)
P1	4.2	0.853	17.728	0.663	1.003
P4	5.3	1.238	16.108	0.663	1.003
P7	3.7	0.681	20.220	0.663	1.003
P10	4.16	0.802	14.706	0.663	1.003
P22	2.8	0.414	41.393	0.663	1.003
P25	2.75	0.384	33.580	0.663	1.003
P28	2	0.236	50.465	0.663	1.003
A1	15	3.212	5.544	0.663	1.003
A4	13	2.553	6.048	0.663	1.003
A7	9.4	1.387	9.751	0.663	1.003
A10	8.4	1.162	8.140	0.663	1.003
A19	23	6.645	4.716	0.663	1.003
A22	20	5.219	5.414	0.663	1.003
A25	17.2	4.038	5.388	0.663	1.003
A28	12.2	2.308	10.720	0.663	1.003
A31	11.6	2.067	9.723	0.663	1.003
A34	10.6	1.729	8.804	0.663	1.003
B1	49.5	13.770	3.120	0.663	1.003
B4	44	11.212	3.270	0.663	1.003
B7	34	7.122	5.407	0.663	1.003
B10	36	7.877	5.050	0.663	1.003
B16	33	6.610	3.003	0.663	1.003
B19	25	4.332	6.821	0.663	1.003

Test Liquid 20: Methocel 0.65%
Density, ρ_f =1000 kg/m^3; n=0.689; k=0.662(P.S^n); Temp=289K

Particle ID	$V_\infty x10^2$ (m/s)	Re_∞'	CD_∞	n	k(P.S^n)
P1	6.6	2.275	7.179	0.689	0.662
P4	7.75	2.996	7.533	0.689	0.662
P7	5.75	1.795	8.372	0.689	0.662
P10	6	1.924	7.069	0.689	0.662
P13	5.1	1.446	7.435	0.689	0.662
P22	4.5	1.143	16.026	0.689	0.662
P25	3.75	0.851	18.059	0.689	0.662
P28	3	0.595	22.429	0.689	0.662
A1	19.8	6.497	3.182	0.689	0.662
A4	17.5	5.310	3.338	0.689	0.662
A7	12.2	2.755	5.789	0.689	0.662
A10	11	2.339	4.747	0.689	0.662
A19	31.5	14.037	2.514	0.689	0.662
A22	28	11.363	2.762	0.689	0.662
A25	23.2	8.387	2.961	0.689	0.662
A28	19	5.817	4.420	0.689	0.662
A31	17	4.809	4.527	0.689	0.662
A34	14.8	3.775	4.516	0.689	0.662
B1	68	28.276	1.653	0.689	0.662
B4	58.2	21.936	1.869	0.689	0.662
B7	46.2	14.470	2.928	0.689	0.662
B10	41	12.689	3.894	0.689	0.662
B16	40	11.553	2.044	0.689	0.662
B19	33.5	8.681	3.798	0.689	0.662

Test Liquid 21: Methocel 0.5%
Density, ρ_f =1000 kg/m^3; n=0.690; k=0.383(P.S^n); Temp=289K

Particle ID	$V_\infty x10^2$ (m/s)	Re_∞'	CD_∞	n	k(P.S^n)
P1	14	10.363	1.554	0.696	0.383
P4	16.3	13.492	1.703	0.696	0.383
P7	12.8	8.713	1.689	0.696	0.383
P10	13.2	9.196	1.461	0.696	0.383
P13	11	6.736	1.598	0.696	0.383
P22	10.2	5.681	3.121	0.696	0.383

P25	7	3.285	5.183	0.696	0.383
P28	7.8	3.544	3.318	0.696	0.383
A1	32	20.522	1.218	0.696	0.383
A4	29.5	17.727	1.175	0.696	0.383
A7	24	11.257	1.496	0.696	0.383
A10	22.5	10.060	1.135	0.696	0.383
A19	52.6	46.190	0.902	0.696	0.383
A22	42	32.519	1.228	0.696	0.383
A25	36.7	25.743	1.183	0.696	0.383
A28	35	21.786	1.302	0.696	0.383
A31	31.5	18.155	1.319	0.696	0.383
A34	28.5	14.989	1.218	0.696	0.383
B1	83	61.300	1.110	0.696	0.383
B4	73	49.305	1.188	0.696	0.383
B7	60	34.049	1.736	0.696	0.383
B10	58	33.417	1.946	0.696	0.383
B16	55	29.307	1.081	0.696	0.383
B19	45	21.374	2.105	0.696	0.383

Appendix B: WALL FACTOR DATA

Newtonian media

I. SPHERE

Test Liquid 2: Glucose Solution 90%

ρ_f =1359 kg/m3; μ=4.5 Pa.s; Temp=298 K.

Particle ID	Tube ID	d/D	$v x 10^2$(m/s)	$V_\infty x 10^2$(m/s)	$f_w = v/V_\infty$
S6	Tb1	0.148	2.393	3.5	0.684
	Tb3	0.104	2.710	3.5	0.774
	Tb4	0.079	2.900	3.5	0.829
	Tb5	0.064	3.100	3.5	0.886
S8	Tb1	0.197	3.238	5	0.648
	Tb3	0.139	3.796	5	0.759
	Tb4	0.106	4.075	5	0.815
	Tb5	0.084	4.277	5	0.855
S10	Tb1	0.246	3.876	7.5	0.517
	Tb3	0.174	4.944	7.5	0.659
	Tb4	0.132	5.510	7.5	0.735
	Tb5	0.106	6.251	7.5	0.833
S12	Tb1	0.296	4.839	11	0.440
	Tb3	0.209	6.446	11	0.586
	Tb4	0.159	7.258	11	0.660
	Tb5	0.127	8.208	11	0.746
G_G	Tb1	0.493	0.788	4.4	0.179
	Tb3	0.348	1.458	4.4	0.331
	Tb4	0.265	2.115	4.4	0.481
	Tb5	0.212	2.789	4.4	0.634
G_GB	Tb1	0.505	0.858	4.6	0.186
	Tb3	0.357	1.668	4.6	0.363
	Tb4	0.271	2.147	4.6	0.467
	Tb5	0.217	2.885	4.6	0.627
G_VS	Tb1	0.312	0.993	2.4	0.414
	Tb3	0.221	1.293	2.4	0.539
	Tb4	0.168	1.591	2.4	0.663
	Tb5	0.134	1.732	2.4	0.722
G_S	Tb1	0.308	0.859	1.9	0.452
	Tb3	0.217	1.002	1.9	0.527
	Tb4	0.165	1.401	1.9	0.737
	Tb5	0.132	1.515	1.9	0.797
T6	Tb1	0.148	0.273	0.4	0.682
	Tb3	0.104	0.315	0.4	0.786
	Tb4	0.079	0.327	0.4	0.818
	Tb5	0.064	0.349	0.4	0.873
T8	Tb1	0.197	0.418	0.7	0.597
	Tb3	0.139	0.445	0.7	0.636

	Tb4	0.106	0.532	0.7	0.760
	Tb5	0.084	0.598	0.7	0.854
T10	Tb1	0.246	0.524	1	0.524
	Tb3	0.174	0.676	1	0.676
	Tb4	0.132	0.781	1	0.781
	Tb5	0.106	0.815	1	0.815

Test Liquid 3: Glucose Solution 85%

ρ_f =1349 kg/m3; μ=1.6 Pa.s; Temp=298 K.

Particle ID		d/D	$v x 10^2$(m/s)	$V_\infty x 10^2$(m/s)	$f_w = v/V_\infty$
S6	Tb1	0.148	8.110	12	0.676
	Tb3	0.104	8.315	12	0.693
	Tb4	0.079	9.693	12	0.808
	Tb5	0.064	10.233	12	0.853
S8	Tb1	0.197	10.891	18	0.605
	Tb3	0.139	12.099	18	0.672
	Tb4	0.106	14.048	18	0.780
	Tb5	0.084	15.142	18	0.841
S10	Tb1	0.246	13.723	24	0.572
	Tb3	0.174	16.443	24	0.685
	Tb4	0.132	18.534	24	0.772
	Tb5	0.106	19.589	24	0.816
S12	Tb1	0.296	18.671	37	0.505
	Tb3	0.209	24.148	37	0.653
	Tb4	0.159	26.792	37	0.724
	Tb5	0.127	29.491	37	0.797
G_B	Tb1	0.727	1.799	27	0.066
	Tb3	0.513	9.766	27	0.359
	Tb4	0.390	13.487	27	0.496
	Tb5	0.313	16.321	27	0.600
G_DB	Tb1	0.601	2.702	23.5	0.115
	Tb3	0.424	8.079	23.5	0.344
	Tb4	0.323	12.527	23.5	0.533
	Tb5	0.258	14.332	23.5	0.610
G_G	Tb1	0.493	3.894	17	0.229
	Tb3	0.348	7.195	17	0.423
	Tb4	0.265	10.042	17	0.591
	Tb5	0.212	11.523	17	0.678
G_GB	Tb1	0.505	4.037	18	0.224
	Tb3	0.357	7.834	18	0.435
	Tb4	0.271	10.967	18	0.609
	Tb5	0.217	12.001	18	0.667
G_S	Tb1	0.312	4.574	11	0.416
	Tb3	0.221	5.756	11	0.523
	Tb4	0.168	7.384	11	0.671
	Tb5	0.134	8.532	11	0.776
G_VS	Tb1	0.308	3.474	9	0.386
	Tb3	0.217	4.629	9	0.514
	Tb4	0.165	5.998	9	0.666

	Tb5	0.132	6.542	9	0.727
T6	Tb1	0.148	0.988	1.4	0.706
	Tb3	0.104	1.063	1.4	0.759
	Tb4	0.079	1.180	1.4	0.843
	Tb5	0.064	1.258	1.4	0.898
T8	Tb1	0.197	1.500	2.6	0.577
	Tb3	0.139	1.718	2.6	0.661
	Tb4	0.106	1.982	2.6	0.762
	Tb5	0.084	2.124	2.6	0.817
T10	Tb1	0.246	1.959	3.9	0.502
	Tb3	0.174	2.431	3.9	0.623
	Tb4	0.132	2.806	3.9	0.720
	Tb5	0.106	3.120	3.9	0.800

Test Liquid 4: Glucose Solution 80%

ρ_f =1318 kg/m3; μ=0.41 Pa.s; Temp=299 K.

Particle ID/Tube ID		d/D	$v x 10^2$(m/s)	$V_\infty x 10^2$(m/s)	$f_w = v/V_\infty$
T6	Tb1	0.148	3.594	4.9	0.148
	Tb3	0.104	3.812	4.9	0.104
	Tb4	0.079	4.165	4.9	0.079
	Tb5	0.064	4.374	4.9	0.064
T8	Tb1	0.197	5.676	7.8	0.728
	Tb3	0.139	6.005	7.8	0.770
	Tb4	0.106	6.771	7.8	0.868
	Tb5	0.084	6.893	7.8	0.884
T10	Tb1	0.246	7.393	10.8	0.685
	Tb3	0.174	8.784	10.8	0.813
	Tb4	0.132	9.134	10.8	0.846
	Tb5	0.106	9.185	10.8	0.850
S6	Tb1	0.148	25.098	29	0.865
	Tb3	0.104	25.771	29	0.889
	Tb4	0.079	26.728	29	0.922
	Tb5	0.064	27.587	29	0.951
S8	Tb1	0.197	30.639	37.9	0.808
	Tb3	0.139	32.058	37.9	0.846
	Tb4	0.106	33.525	37.9	0.885
	Tb5	0.084	35.169	37.9	0.928
S10	Tb1	0.246	37.620	47.4	0.794
	Tb3	0.174	40.393	47.4	0.852
	Tb4	0.132	42.351	47.4	0.893
	Tb5	0.106	43.078	47.4	0.909
S12	Tb1	0.296	50.383	63.1	0.798
	Tb3	0.209	53.464	63.1	0.847
	Tb4	0.159	55.789	63.1	0.884
	Tb5	0.127	58.035	63.1	0.920
G_DB	Tb1	0.601	10.566	41.6	0.254
	Tb3	0.424	19.770	41.6	0.475
	Tb4	0.323	25.274	41.6	0.608
	Tb5	0.258	28.034	41.6	0.674

G_S	Tb1	0.312	13.741	25.3	0.550
	Tb3	0.221	16.663	25.3	0.667
	Tb4	0.168	19.679	25.3	0.787
	Tb5	0.134	20.027	25.3	0.801
G_GB	Tb1	0.505	14.881	37.4	0.398
	Tb3	0.357	20.967	37.4	0.561
	Tb4	0.271	25.750	37.4	0.689
	Tb5	0.217	27.493	37.4	0.735
G_VS	Tb1	0.308	12.562	20.7	0.497
	Tb3	0.217	14.782	20.7	0.584
	Tb4	0.165	15.401	20.7	0.609
	Tb5	0.132	17.819	20.7	0.704
G_G	Tb1	0.493	13.789	33.4	0.413
	Tb3	0.348	17.221	33.4	0.516
	Tb4	0.265	22.550	33.4	0.675
	Tb5	0.212	24.758	33.4	0.741

Test Liquid 5: Glucose Solution 75%

ρ_f=1310 kg/m3; μ=0.302 Pa.s; Temp=299 K

Particle ID/Tube ID		d/D	$v\times10^2$(m/s)	$V_\infty\times10^2$(m/s)	$f_w = v/V_\infty$
T6	Tb1	0.148	3.827	5.5	0.696
	Tb3	0.104	4.396	5.5	0.799
	Tb4	0.079	4.444	5.5	0.808
	Tb5	0.064	4.958	5.5	0.901
T8	Tb1	0.197	5.754	9	0.639
	Tb3	0.139	6.718	9	0.746
	Tb4	0.106	7.041	9	0.782
	Tb5	0.084	7.884	9	0.876
T10	Tb1	0.246	7.614	12.5	0.609
	Tb3	0.174	9.423	12.5	0.754
	Tb4	0.132	9.795	12.5	0.784
	Tb5	0.106	10.456	12.5	0.836
S6	Tb1	0.148	25.050	29	0.864
	Tb3	0.104	26.776	29	0.923
	Tb4	0.079	26.941	29	0.929
	Tb5	0.064	27.411	29	0.945
S8	Tb1	0.197	32.279	42	0.769
	Tb3	0.139	34.035	42	0.810
	Tb4	0.106	36.276	42	0.864
	Tb5	0.084	38.100	42	0.907
S10	Tb1	0.246	37.944	54	0.703
	Tb3	0.174	41.889	54	0.776
	Tb4	0.132	44.924	54	0.832
	Tb5	0.106	46.939	54	0.869
S12	Tb1	0.296	49.272	75	0.657
	Tb3	0.209	56.327	75	0.751
	Tb4	0.159	61.472	75	0.820
	Tb5	0.127	63.479	75	0.846
G_DB	Tb1	0.601	12.873	52	0.368

	Tb3	0.424	25.611	52	0.493
	Tb4	0.323	33.525	52	0.645
	Tb5	0.258	37.521	52	0.722
G_S	Tb1	0.312	16.954	25	0.678
	Tb3	0.221	19.143	25	0.766
	Tb4	0.168	20.539	25	0.822
	Tb5	0.134	21.579	25	0.863
G_GB	Tb1	0.505	15.658	43	0.364
	Tb3	0.357	25.258	43	0.587
	Tb4	0.271	27.899	43	0.649
	Tb5	0.217	31.279	43	0.727
G_VS	Tb1	0.308	14.124	19	0.673
	Tb3	0.217	14.684	19	0.773
	Tb4	0.165	16.101	19	0.847
	Tb5	0.132	17.494	19	0.921
G_G	Tb1	0.493	14.548	39	0.373
	Tb3	0.348	23.059	39	0.591
	Tb4	0.265	25.362	39	0.650
	Tb5	0.212	29.169	39	0.748

Test Liquid 6: Glucose Solution 70%

ρ_f=1296 kg/m3; μ=0.15 Pa.s; Temp=298 K.

Particle ID/Tube ID		d/D	$vx10^2$(m/s)	$V_\infty x10^2$(m/s)	$f_w = v/V_\infty$
T6	Tb1	0.148	7.591	9.6	0.791
	Tb3	0.104	7.725	9.6	0.805
	Tb4	0.079	8.361	9.6	0.871
	Tb5	0.064	8.897	9.6	0.927
T8	Tb1	0.197	11.176	13.8	0.810
	Tb3	0.139	11.291	13.8	0.818
	Tb4	0.106	12.295	13.8	0.891
	Tb5	0.084	12.775	13.8	0.926
T10	Tb1	0.246	14.364	18.9	0.760
	Tb3	0.174	15.156	18.9	0.802
	Tb4	0.132	16.481	18.9	0.872
	Tb5	0.106	17.003	18.9	0.900
S6	Tb1	0.148	37.031	42.7	0.867
	Tb3	0.104	39.076	42.7	0.915
	Tb4	0.079	39.642	42.7	0.928
	Tb5	0.064	40.211	42.7	0.942
S8	Tb1	0.197	47.515	55.2	0.861
	Tb3	0.139	49.442	55.2	0.896
	Tb4	0.106	51.020	55.2	0.924
	Tb5	0.084	52.002	55.2	0.942
S10	Tb1	0.246	56.667	62.3	0.910
	Tb3	0.174	57.897	62.3	0.929
	Tb4	0.132	58.842	62.3	0.944
	Tb5	0.106	60.191	62.3	0.966
S12	Tb1	0.296	71.752	79.2	0.906
	Tb3	0.209	72.144	79.2	0.911

	Tb4	0.159	74.002	79.2	0.934
	Tb5	0.127	76.977	79.2	0.972
G_DB	Tb1	0.601	21.855	67	0.364
	Tb3	0.424	35.601	67	0.531
	Tb4	0.323	44.595	67	0.666
	Tb5	0.258	46.372	67	0.692
G_S	Tb1	0.312	25.997	36	0.722
	Tb3	0.221	27.382	36	0.761
	Tb4	0.168	30.436	36	0.845
	Tb5	0.134	32.045	36	0.890
G_GB	Tb1	0.505	27.012	53.2	0.508
	Tb3	0.357	36.033	53.2	0.677
	Tb4	0.271	39.599	53.2	0.744
	Tb5	0.217	41.556	53.2	0.781
G_VS	Tb1	0.308	23.007	28	0.822
	Tb3	0.217	24.778	28	0.885
	Tb4	0.165	25.668	28	0.917
	Tb5	0.132	26.378	28	0.942
G_G	Tb1	0.493	25.778	50.3	0.512
	Tb3	0.348	34.274	50.3	0.681
	Tb4	0.265	37.108	50.3	0.738
	Tb5	0.212	39.633	50.3	0.788

Test Liquid 7: Glucose Solution 65%

ρ_f=1250 kg/m3; μ=0.045 Pa.s; Temp=298 K.

Particle ID/Tube ID		d/D	$vx10^2$(m/s)	$V_\infty x10^2$(m/s)	$f_w = v/V_\infty$
T6	Tb1	0.147783	14.33265	18.2	0.787508
	Tb3	0.104348	15.08131	18.2	0.828643
	Tb4	0.079365	16.01633	18.2	0.880018
	Tb5	0.063559	16.61335	18.2	0.912822
T8	Tb1	0.197044	19.24454	22.4	0.859131
	Tb3	0.13913	20.19709	22.4	0.901656
	Tb4	0.10582	20.67228	22.4	0.92287
	Tb5	0.084299	21.09152	22.4	0.941586
T10	Tb1	0.246305	23.48769	28.7	0.818387
	Tb3	0.173913	24.7678	28.7	0.86299
	Tb4	0.132275	25.60927	28.7	0.892309
	Tb5	0.105932	26.68529	28.7	0.929801
S6	Tb1	0.147783	56.18437	64	0.877881
	Tb3	0.104348	57.97873	64	0.905918
	Tb4	0.079365	59.41948	64	0.928429
	Tb5	0.063559	60.94742	64	0.952303
S8	Tb1	0.197044	65.6814	77.6	0.84641
	Tb3	0.13913	68.66574	77.6	0.884868
	Tb4	0.10582	70.30354	77.6	0.905973
	Tb5	0.084299	73.14519	77.6	0.942593
S10	Tb1	0.246305	72.23874	89	0.811671
	Tb3	0.173913	76.6743	89	0.861509
	Tb4	0.132275	79.04762	89	0.888175

	Tb5	0.105932	82.60536	89	0.92815
S12	Tb1	0.295567	90.44444	112.4	0.804666
	Tb3	0.208696	95.70889	112.4	0.851503
	Tb4	0.15873	100.0278	112.4	0.889927
	Tb5	0.127119	103.4885	112.4	0.920716
G_B	Tb1	0.726601	20.59596	90	0.228844
	Tb3	0.513043	46.66949	90	0.51855
	Tb4	0.390212	52.46847	90	0.582983
	Tb5	0.3125	59.79314	90	0.664368
G_DB	Tb1	0.600985	26.96163	76.3	0.353363
	Tb3	0.424348	40.7836	76.3	0.534516
	Tb4	0.322751	49.78903	76.3	0.652543
	Tb5	0.258475	55.1797	76.3	0.723194
G_S	Tb1	0.312315	34.78839	42.5	0.81855
	Tb3	0.220522	36.76937	42.5	0.865162
	Tb4	0.167725	37.65831	42.5	0.886078
	Tb5	0.134322	39.66737	42.5	0.93335
G_GB	Tb1	0.504926	32.7817	62.9	0.521172
	Tb3	0.356522	39.66047	62.9	0.630532
	Tb4	0.271164	46.76834	62.9	0.743535
	Tb5	0.217161	50.11829	62.9	0.796793
G_G	Tb1	0.492611	30.78804	61.5	0.500619
	Tb3	0.347826	38.04098	61.5	0.618553
	Tb4	0.26455	45.00937	61.5	0.73186
	Tb5	0.211864	48.50515	61.5	0.788702
G_VS	Tb1	0.307882	33.87958	40	0.84699
	Tb3	0.217391	35.35193	40	0.883798
	Tb4	0.165344	36.20996	40	0.905249
	Tb5	0.132415	37.90047	40	0.947512

Test Liquid 8: Glucose Solution 60%
ρ_f=1219 kg/m3; μ=0.02 Pa.s; Temp=298K.

Particle ID/Tube ID		d/D	$vx10^2$(m/s)	$V_\infty x10^2$(m/s)	$f_w = v/V_\infty$
T6	Tb1	0.148	1.295	3	0.432
	Tb3	0.104	1.731	3	0.577
	Tb4	0.079	2.101	3	0.700
	Tb5	0.064	2.366	3	0.789
T8	Tb1	0.197	2.767	5.6	0.494
	Tb3	0.139	3.343	5.6	0.597
	Tb4	0.106	4.053	5.6	0.724
	Tb5	0.084	4.534	5.6	0.810
T10	Tb1	0.246	4.216	8.2	0.514
	Tb3	0.174	5.182	8.2	0.632
	Tb4	0.132	6.060	8.2	0.739
	Tb5	0.106	6.636	8.2	0.809
S6	Tb1	0.148	13.905	22	0.632
	Tb3	0.104	15.761	22	0.716
	Tb4	0.079	16.611	22	0.755
	Tb5	0.064	17.548	22	0.798

S8	Tb1	0.197	40.680	30	0.726
	Tb3	0.139	42.404	30	0.757
	Tb4	0.106	44.511	30	0.795
	Tb5	0.084	48.242	30	0.861
S10	Tb1	0.246	29.637	45	0.659
	Tb3	0.174	33.187	45	0.737
	Tb4	0.132	36.221	45	0.805
	Tb5	0.106	38.623	45	0.858
S12	Tb1	0.296	39.884	55	0.725
	Tb3	0.209	43.914	55	0.798
	Tb4	0.159	46.682	55	0.849
	Tb5	0.127	48.777	55	0.887
G_DB	Tb1	0.601	8.393	46	0.280
	Tb3	0.424	20.196	46	0.439
	Tb4	0.323	28.096	46	0.611
	Tb5	0.258	30.247	46	0.658
G_S	Tb1	0.312	9.913	20	0.496
	Tb3	0.221	14.081	20	0.704
	Tb4	0.168	16.866	20	0.843
	Tb5	0.134	17.362	20	0.868
G_GB	Tb1	0.505	12.018	38	0.316
	Tb3	0.357	19.497	38	0.513
	Tb4	0.271	23.856	38	0.628
	Tb5	0.217	26.667	38	0.702
G_G	Tb1	0.493	11.232	36	0.312
	Tb3	0.348	18.330	36	0.509
	Tb4	0.265	22.216	36	0.617
	Tb5	0.212	25.333	36	0.704
G_VS	Tb1	0.308	8.213	16	0.513
	Tb3	0.217	11.967	16	0.748
	Tb4	0.165	13.441	16	0.840
	Tb5	0.132	15.578	16	0.974

II. CONES

Test Liquid 1: Glucose Solution 95%

ρ_f = 1439 kg/m3; μ=12.7 Pa.s; Temp=302 K.

Particle ID/Tube ID		d/D	$v x 10^2$(m/s)	$V_\infty x 10^2$(m/s)	$f_w = v/V_\infty$
A1	Tb1	0.234	0.130	0.22	0.590
	Tb2	0.188	0.138	0.22	0.625
	Tb3	0.165	0.158	0.22	0.717
	Tb4	0.126	0.162	0.22	0.735
	Tb5	0.101	0.183	0.22	0.832
A4	Tb1	0.234	0.116	0.16	0.578
	Tb2	0.188	0.135	0.16	0.675
	Tb3	0.165	0.140	0.16	0.698
	Tb4	0.126	0.159	0.16	0.793
	Tb5	0.101	0.160	0.16	0.802
A7	Tb1	0.172	0.084	0.11	0.649

	Tb2	0.139	0.096	0.11	0.740
	Tb3	0.122	0.100	0.11	0.771
	Tb4	0.093	0.106	0.11	0.817
	Tb5	0.074	0.109	0.11	0.838
A10	Tb1	0.172	0.078	0.1	0.711
	Tb2	0.139	0.085	0.1	0.772
	Tb3	0.122	0.090	0.1	0.817
	Tb4	0.093	0.094	0.1	0.854
	Tb5	0.074	0.097	0.1	0.881
A13	Tb1	0.234	0.069	0.1	0.657
	Tb2	0.188	0.075	0.1	0.710
	Tb3	0.165	0.083	0.1	0.787
	Tb4	0.126	0.084	0.1	0.800
	Tb5	0.101	0.089	0.1	0.849
A16	Tb1	0.197	0.051	0.06	0.638
	Tb2	0.158	0.058	0.06	0.726
	Tb3	0.139	0.059	0.06	0.739
	Tb4	0.106	0.062	0.06	0.773
	Tb5	0.085	0.066	0.06	0.829
A19	Tb1	0.234	0.220	0.37	0.595
	Tb2	0.188	0.246	0.37	0.665
	Tb3	0.165	0.265	0.37	0.715
	Tb4	0.126	0.287	0.37	0.775
	Tb5	0.101	0.307	0.37	0.831
A22	Tb1	0.234	0.195	0.31	0.630
	Tb2	0.188	0.205	0.31	0.661
	Tb3	0.165	0.224	0.31	0.723
	Tb4	0.126	0.242	0.31	0.780
	Tb5	0.101	0.265	0.31	0.854
A25	Tb1	0.234	0.150	0.26	0.577
	Tb2	0.188	0.167	0.26	0.642
	Tb3	0.165	0.175	0.26	0.673
	Tb4	0.126	0.198	0.26	0.761
	Tb5	0.101	0.217	0.26	0.834
A28	Tb1	0.172	0.127	0.21	0.667
	Tb2	0.139	0.139	0.21	0.729
	Tb3	0.122	0.146	0.21	0.767
	Tb4	0.093	0.159	0.21	0.838
	Tb5	0.074	0.161	0.21	0.847
A31	Tb1	0.172	0.116	0.17	0.684
	Tb2	0.139	0.121	0.17	0.709
	Tb3	0.122	0.130	0.17	0.767
	Tb4	0.093	0.140	0.17	0.821
	Tb5	0.074	0.145	0.17	0.853
A34	Tb1	0.172	0.100	0.15	0.690
	Tb2	0.139	0.106	0.15	0.732
	Tb3	0.122	0.113	0.15	0.776
	Tb4	0.093	0.121	0.15	0.834
	Tb5	0.074	0.126	0.15	0.870

B1 Tb1	0.148	1.983	2.45	0.809
Tb2	0.119	2.010	2.45	0.820
Tb3	0.104	2.105	2.45	0.859
Tb4	0.079	2.170	2.45	0.886
Tb5	0.064	2.254	2.45	0.920
B4 Tb1	0.148	1.484	1.9	0.781
Tb2	0.119	1.549	1.9	0.815
Tb3	0.104	1.585	1.9	0.834
Tb4	0.079	1.631	1.9	0.858
Tb5	0.064	1.764	1.9	0.928
B7 Tb1	0.116	1.384	1.61	0.860
Tb2	0.093	1.392	1.61	0.865
Tb3	0.082	1.439	1.61	0.894
Tb4	0.062	1.497	1.61	0.930
Tb5	0.050	1.512	1.61	0.939
B10 Tb1	0.148	1.230	1.5	0.820
Tb2	0.119	1.282	1.5	0.855
Tb3	0.104	1.305	1.5	0.870
Tb4	0.079	1.338	1.5	0.892
Tb5	0.064	1.391	1.5	0.927
B13 Tb1	0.148	0.477	0.6	0.794
Tb2	0.119	0.512	0.6	0.854
Tb3	0.104	0.534	0.6	0.890
Tb4	0.079	0.544	0.6	0.907
Tb5	0.064	0.562	0.6	0.937
B16 Tb1	0.116	0.749	0.6	0.851
Tb2	0.093	0.786	0.6	0.893
Tb3	0.082	0.798	0.6	0.907
Tb4	0.062	0.818	0.6	0.930
Tb5	0.050	0.824	0.6	0.936
B19 Tb1	0.116	0.508	0.75	0.833
Tb2	0.093	0.528	0.75	0.866
Tb3	0.082	0.541	0.75	0.887
Tb4	0.062	0.554	0.75	0.909
Tb5	0.050	0.565	0.75	0.926
Ba Tb1	0.116	0.455	0.58	0.784
Tb2	0.093	0.476	0.58	0.820
Tb3	0.082	0.500	0.58	0.861
Tb4	0.062	0.500	0.58	0.863
Tb5	0.050	0.522	0.58	0.901

Test Liquid 2: Glucose Solution 90%

ρ_f=1359 kg/m3; μ=4.5 Pa.s; Temp=298 K.

Particle ID/Tube ID	d/D	vx10^2(m/s)	V_∞x10^2(m/s)	$f_w = v/V_\infty$
A1 Tb1	0.234	0.867	1.4	0.619
Tb3	0.165	0.976	1.4	0.697
Tb4	0.126	1.084	1.4	0.774
Tb5	0.101	1.188	1.4	0.848
A4 Tb1	0.234	0.722	1.25	0.577

	Tb3	0.165	0.868	1.25	0.695
	Tb4	0.126	0.978	1.25	0.782
	Tb5	0.101	1.008	1.25	0.807
A19	Tb1	0.234	1.524	2.3	0.662
	Tb3	0.165	1.683	2.3	0.732
	Tb4	0.126	1.865	2.3	0.811
	Tb5	0.101	1.988	2.3	0.864
A22	Tb1	0.234	1.285	1.81	0.714
	Tb3	0.165	1.398	1.81	0.777
	Tb4	0.126	1.509	1.81	0.838
	Tb5	0.101	1.611	1.81	0.895
A25	Tb1	0.234	1.048	1.6	0.635
	Tb3	0.165	1.187	1.6	0.720
	Tb4	0.126	1.297	1.6	0.786
	Tb5	0.101	1.384	1.6	0.839
A28	Tb1	0.172	0.926	1.35	0.686
	Tb3	0.122	0.998	1.35	0.740
	Tb4	0.093	1.100	1.35	0.815
	Tb5	0.074	1.190	1.35	0.882
A31	Tb1	0.172	0.719	1	0.654
	Tb3	0.122	0.766	1	0.697
	Tb4	0.093	0.848	1	0.771
	Tb5	0.074	0.892	1	0.811
A34	Tb1	0.172	0.683	0.9	0.759
	Tb3	0.122	0.723	0.9	0.804
	Tb4	0.093	0.780	0.9	0.866
	Tb5	0.074	0.828	0.9	0.920
A7	Tb1	0.172	0.536	0.7	0.766
	Tb3	0.122	0.561	0.7	0.801
	Tb4	0.093	0.616	0.7	0.881
	Tb5	0.074	0.653	0.7	0.933
A10	Tb1	0.172	0.489	0.65	0.753
	Tb3	0.122	0.520	0.65	0.799
	Tb4	0.093	0.561	0.65	0.863
	Tb5	0.074	0.585	0.65	0.900
A13	Tb1	0.234	0.351	0.52	0.626
	Tb3	0.165	0.384	0.52	0.687
	Tb4	0.126	0.425	0.52	0.759
	Tb5	0.101	0.452	0.52	0.806
A16	Tb1	0.172	0.308	0.42	0.769
	Tb3	0.122	0.338	0.42	0.844
	Tb4	0.093	0.350	0.42	0.876
	Tb5	0.074	0.378	0.42	0.945
B1	Tb1	0.148	4.860	6	0.810
	Tb3	0.104	5.259	6	0.877
	Tb4	0.079	5.355	6	0.892
	Tb5	0.064	5.482	6	0.914
B4	Tb1	0.148	3.875	6	0.791
	Tb3	0.104	4.097	4.9	0.836

	Tb4	0.079	4.237	4.9	0.865
	Tb5	0.064	4.521	4.9	0.923
B7	Tb1	0.116	3.494	4.1	0.852
	Tb3	0.082	3.664	4.1	0.894
	Tb4	0.062	3.747	4.1	0.914
	Tb5	0.050	3.831	4.1	0.934
B10	Tb1	0.116	1.361	1.65	0.825
	Tb3	0.082	1.403	1.65	0.851
	Tb4	0.062	1.459	1.65	0.884
	Tb5	0.050	1.559	1.65	0.945
B13	Tb1	0.116	1.361	1.65	0.825
	Tb3	0.082	1.403	1.65	0.851
	Tb4	0.062	1.459	1.65	0.884
	Tb5	0.050	1.559	1.65	0.945
B16	Tb1	0.116	1.361	1.65	0.825
	Tb3	0.082	1.403	1.65	0.851
	Tb4	0.062	1.459	1.65	0.884
	Tb5	0.050	1.559	1.65	0.945
B19	Tb1	0.116	1.361	1.65	0.825
	Tb3	0.082	1.403	1.65	0.851
	Tb4	0.062	1.459	1.65	0.884
	Tb5	0.050	1.559	1.65	0.945

Test Liquid 3: Glucose Solution 85%
ρ_f=1349 kg/m3; μ=1.6 Pa.s; Temp=298 K.

Particle ID/Tube ID		d/D	$v\times10^2$(m/s)	$V_\infty\times10^2$(m/s)	$f_w = v/V_\infty$
A1	Tb1	0.234	3.407	5.3	0.643
	Tb3	0.165	3.941	5.3	0.744
	Tb4	0.126	4.238	5.3	0.800
	Tb5	0.101	4.563	5.3	0.861
A4	Tb1	0.234	2.713	4	0.617
	Tb3	0.165	3.184	4	0.724
	Tb4	0.126	3.461	4	0.786
	Tb5	0.101	3.678	4	0.836
A19	Tb1	0.234	5.244	8.2	0.639
	Tb3	0.165	5.931	8.2	0.723
	Tb4	0.126	6.489	8.2	0.791
	Tb5	0.101	7.003	8.2	0.854
A22	Tb1	0.234	4.585	6.6	0.695
	Tb3	0.165	4.884	6.6	0.740
	Tb4	0.126	5.540	6.6	0.839
	Tb5	0.101	6.000	6.6	0.909
A25	Tb1	0.234	3.946	6.1	0.647
	Tb3	0.165	4.499	6.1	0.738
	Tb4	0.126	4.841	6.1	0.794
	Tb5	0.101	5.257	6.1	0.862
A28	Tb1	0.172	3.372	4.4	0.766

	Tb3	0.122	3.716	4.4	0.845
	Tb4	0.093	4.049	4.4	0.920
	Tb5	0.074	4.244	4.4	0.965
A31	Tb1	0.172	2.479	3.7	0.670
	Tb3	0.122	2.755	3.7	0.745
	Tb4	0.093	2.988	3.7	0.808
	Tb5	0.074	3.233	3.7	0.874
A34	Tb1	0.172	2.282	3.4	0.683
	Tb3	0.122	2.514	3.4	0.753
	Tb4	0.093	2.731	3.4	0.818
	Tb5	0.074	2.916	3.4	0.873
A7	Tb1	0.172	1.652	2.4	0.688
	Tb3	0.122	1.725	2.4	0.719
	Tb4	0.093	1.966	2.4	0.819
	Tb5	0.074	2.100	2.4	0.875
A10	Tb1	0.172	1.127	1.8	0.626
	Tb3	0.122	1.256	1.8	0.698
	Tb4	0.093	1.468	1.8	0.816
	Tb5	0.074	1.537	1.8	0.854
A13	Tb1	0.234	1.215	2	0.607
	Tb3	0.165	1.400	2	0.700
	Tb4	0.126	1.521	2	0.761
	Tb5	0.101	1.702	2	0.851
A16	Tb1	0.172	0.870	1.5	0.600
	Tb3	0.122	1.021	1.5	0.704
	Tb4	0.093	1.097	1.5	0.757
	Tb5	0.074	1.204	1.5	0.830
B1	Tb1	0.148	16.752	20	0.817
	Tb3	0.104	17.424	20	0.850
	Tb4	0.079	18.219	20	0.889
	Tb5	0.064	19.074	20	0.930
B4	Tb1	0.148	14.249	18	0.792
	Tb3	0.104	14.738	18	0.819
	Tb4	0.079	15.732	18	0.874
	Tb5	0.064	16.508	18	0.917
B7	Tb1	0.116	10.931	14	0.781
	Tb3	0.082	10.949	14	0.782
	Tb4	0.062	11.647	14	0.832
	Tb5	0.050	13.001	14	0.929
B10	Tb1	0.148	8.869	11	0.806
	Tb3	0.104	9.280	11	0.844
	Tb4	0.079	9.983	11	0.908
	Tb5	0.064	10.036	11	0.912
B16	Tb1	0.116	8.583	10	0.858
	Tb3	0.082	8.835	10	0.883
	Tb4	0.062	9.227	10	0.923
	Tb5	0.050	9.623	10	0.962
B19	Tb1	0.116	6.476	8.2	0.790
	Tb3	0.082	6.931	8.2	0.845

	Tb4	0.062	7.381	8.2	0.900
	Tb5	0.050	7.566	8.2	0.923
B13	Tb1	0.116	5.209	6.7	0.777
	Tb3	0.082	5.530	6.7	0.825
	Tb4	0.062	5.884	6.7	0.878
	Tb5	0.050	6.012	6.7	0.897

Test Liquid 4: Glucose Solution 80%

ρ_f =1318 kg/m3; μ=0.41 Pa.s; Temp=299 K.

Particle ID		d/D	$v\mathrm{x}10^2$(m/s)	$V_\infty \mathrm{x}10^2$(m/s)	$f_w = v/V_\infty$
A1	Tb1	0.234	9.816	13	0.755
	Tb3	0.165	10.772	13	0.829
	Tb4	0.126	11.365	13	0.874
	Tb5	0.101	11.678	13	0.898
A4	Tb1	0.234	7.988	10.8	0.740
	Tb3	0.165	8.798	10.8	0.815
	Tb4	0.126	9.091	10.8	0.842
	Tb5	0.101	9.708	10.8	0.899
A7	Tb1	0.172	6.004	8.4	0.723
	Tb3	0.122	6.580	8.4	0.793
	Tb4	0.093	7.056	8.4	0.850
	Tb5	0.074	7.397	8.4	0.891
A10	Tb1	0.172	5.489	7.2	0.762
	Tb3	0.122	5.837	7.2	0.811
	Tb4	0.093	6.300	7.2	0.875
	Tb5	0.074	6.504	7.2	0.903
A13	Tb1	0.234	3.905	6	0.651
	Tb3	0.165	4.588	6	0.765
	Tb4	0.126	4.730	6	0.788
	Tb5	0.101	5.268	6	0.878
A16	Tb1	0.172	3.326	4.3	0.773
	Tb3	0.122	3.577	4.3	0.832
	Tb4	0.093	3.810	4.3	0.886
	Tb5	0.074	3.906	4.3	0.908
A19	Tb1	0.234	16.927	20.5	0.826
	Tb3	0.165	17.727	20.5	0.865
	Tb4	0.126	18.647	20.5	0.910
	Tb5	0.101	18.858	20.5	0.920
A22	Tb1	0.234	13.496	17	0.794
	Tb3	0.165	14.622	17	0.860
	Tb4	0.126	15.079	17	0.887
	Tb5	0.101	15.427	17	0.907
A25	Tb1	0.234	11.968	15.2	0.725
	Tb3	0.165	12.734	15.2	0.772
	Tb4	0.126	13.574	15.2	0.823
	Tb5	0.101	13.708	15.2	0.831
A28	Tb1	0.172	9.867	12.5	0.731
	Tb3	0.122	10.300	12.5	0.763
	Tb4	0.093	10.750	12.5	0.796

	Tb5	0.074	11.628	12.5	0.861
A31	Tb1	0.172	7.504	10.3	0.736
	Tb3	0.122	8.398	10.3	0.823
	Tb4	0.093	8.632	10.3	0.846
	Tb5	0.074	9.134	10.3	0.896
A34	Tb1	0.172	6.898	9	0.766
	Tb3	0.122	7.441	9	0.827
	Tb4	0.093	7.890	9	0.877
	Tb5	0.074	7.942	9	0.882
B1	Tb1	0.148	34.251	38	0.797
	Tb3	0.104	35.442	38	0.824
	Tb4	0.079	35.600	38	0.828
	Tb5	0.064	36.592	38	0.851
B4	Tb1	0.148	31.832	35	0.816
	Tb3	0.104	32.733	35	0.839
	Tb4	0.079	33.004	35	0.846
	Tb5	0.064	33.699	35	0.864
B7	Tb1	0.116	29.528	32.8	0.844
	Tb3	0.082	30.203	32.8	0.863
	Tb4	0.062	30.820	32.8	0.881
	Tb5	0.050	31.381	32.8	0.897
B10	Tb1	0.148	25.351	30	0.768
	Tb3	0.104	26.712	30	0.809
	Tb4	0.079	27.164	30	0.823
	Tb5	0.064	28.006	30	0.849
B13	Tb1	0.116	17.160	20	0.903
	Tb3	0.082	18.141	20	0.955
	Tb4	0.062	18.401	20	0.968
	Tb5	0.050	18.705	20	0.984
B16	Tb1	0.116	22.233	25	0.794
	Tb3	0.082	22.984	25	0.821
	Tb4	0.062	23.183	25	0.828
	Tb5	0.050	23.811	25	0.850
B19	Tb1	0.116	19.733	22	0.789
	Tb3	0.082	20.128	22	0.805
	Tb4	0.062	20.622	22	0.825
	Tb5	0.050	21.136	22	0.845

Test Liquid 5: Glucose Solution 75%

ρ_f =1310 kg/m3; μ=0.302 Pa.s; Temp=299 K

Particle ID/Tube ID		d/D	$v x10^2$(m/s)	$V_\infty x10^2$(m/s)	$f_w = v/V_\infty$
A1	Tb1	0.234	10.044	14	0.717
	Tb3	0.165	11.148	14	0.796
	Tb4	0.126	11.742	14	0.839
	Tb5	0.101	12.245	14	0.875
A4	Tb1	0.234	8.153	12	0.679
	Tb3	0.165	9.420	12	0.785
	Tb4	0.126	9.604	12	0.800
	A4	0.101	10.425	12	0.869

A7	Tb1	0.172	6.111	9	0.728
	Tb3	0.122	6.897	9	0.821
	Tb4	0.093	7.198	9	0.857
	Tb5	0.074	7.441	9	0.886
A10	Tb1	0.172	4.450	6.6	0.730
	Tb3	0.122	5.258	6.6	0.862
	Tb4	0.093	5.361	6.6	0.879
	Tb5	0.074	5.663	6.6	0.928
A13	Tb1	0.234	4.169	7	0.596
	Tb3	0.165	5.139	7	0.734
	Tb4	0.126	5.302	7	0.757
	Tb5	0.101	5.789	7	0.827
A16	Tb1	0.172	3.328	5.2	0.640
	Tb3	0.122	4.015	5.2	0.772
	Tb4	0.093	4.006	5.2	0.770
	Tb5	0.074	4.579	5.2	0.881
A19	Tb1	0.234	16.479	22	0.749
	Tb3	0.165	17.822	22	0.810
	Tb4	0.126	18.806	22	0.855
	Tb5	0.101	19.720	22	0.896
A22	Tb1	0.234	13.719	17.8	0.771
	Tb3	0.165	14.789	17.8	0.831
	Tb4	0.126	15.646	17.8	0.879
	Tb5	0.101	15.938	17.8	0.895
A25	Tb1	0.234	11.475	15	0.765
	Tb3	0.165	12.786	15	0.852
	Tb4	0.126	13.224	15	0.882
	Tb5	0.101	14.120	15	0.941
A28	Tb1	0.172	10.708	13.5	0.793
	Tb3	0.122	11.413	13.5	0.845
	Tb4	0.093	11.848	13.5	0.878
	Tb5	0.074	12.286	13.5	0.910
A31	Tb1	0.172	8.661	11.5	0.753
	Tb3	0.122	9.694	11.5	0.843
	Tb4	0.093	10.025	11.5	0.872
	Tb5	0.074	10.142	11.5	0.882
A34	Tb1	0.172	8.114	11	0.738
	Tb3	0.122	9.008	11	0.819
	Tb4	0.093	9.523	11	0.866
	Tb5	0.074	9.725	11	0.884
B1	Tb1	0.148	38.915	43	0.905
	Tb3	0.104	39.003	43	0.907
	Tb4	0.079	40.573	43	0.944
	Tb5	0.064	41.532	43	0.966
B4	Tb1	0.148	34.576	39	0.887
	Tb3	0.104	35.349	39	0.906
	Tb4	0.079	36.620	39	0.939
	Tb5	0.064	37.448	39	0.960
B7	Tb1	0.116	31.131	35	0.889

Tb3	0.082	31.921	35	0.912
Tb4	0.062	32.666	35	0.933
Tb5	0.050	33.579	35	0.959
B10 Tb1	0.148	30.079	33	0.911
Tb3	0.104	30.639	33	0.928
Tb4	0.079	31.122	33	0.943
Tb5	0.064	31.986	33	0.969
B13 Tb1	0.116	16.485	19	0.868
Tb3	0.082	17.627	19	0.928
Tb4	0.062	17.806	19	0.937
Tb5	0.050	18.100	19	0.953
B16 Tb1	0.116	24.601	28	0.879
Tb3	0.082	25.296	28	0.903
Tb4	0.062	25.955	28	0.927
Tb5	0.050	26.837	28	0.958
B19 Tb1	0.116	22.453	25	0.898
Tb3	0.082	23.226	25	0.929
Tb4	0.062	23.509	25	0.940
Tb5	0.050	23.933	25	0.957

Test Liquid 6: Glucose Solution 70%
ρ_f=1296 kg/m3; μ=0.15 Pa.s; Temp=298 K.

Particle ID	d/D	$vx10^2$(m/s)	$V_\infty x10^2$(m/s)	$f_w = v/V_\infty$
A1 Tb1	0.234	14.654	18.2	0.805
Tb3	0.165	15.611	18.2	0.858
Tb4	0.126	16.168	18.2	0.888
Tb5	0.101	16.788	18.2	0.922
A4 Tb1	0.234	12.967	16	0.810
Tb3	0.165	13.589	16	0.849
Tb4	0.126	14.277	16	0.892
Tb5	0.101	14.833	16	0.927
A7 Tb1	0.172	10.340	13.3	0.777
Tb3	0.122	10.378	13.3	0.780
Tb4	0.093	11.083	13.3	0.833
Tb5	0.074	11.805	13.3	0.888
A10 Tb1	0.172	9.225	11.7	0.867
Tb3	0.122	9.353	11.7	0.879
Tb4	0.093	9.546	11.7	0.897
Tb5	0.074	10.287	11.7	0.967
A16 Tb1	0.172	6.811	8	0.845
Tb3	0.122	7.133	8	0.885
Tb4	0.093	7.389	8	0.917
Tb5	0.074	7.533	8	0.935
A13 Tb1	0.234	8.266	9.9	0.813
Tb3	0.165	8.704	9.9	0.856
Tb4	0.126	9.023	9.9	0.887
Tb5	0.101	9.447	9.9	0.929
A19 Tb1	0.234	20.181	25.3	0.798
Tb3	0.165	21.625	25.3	0.855

	Tb4	0.126	22.637	25.3	0.895
	Tb5	0.101	23.042	25.3	0.911
A22	Tb1	0.234	18.471	22	0.840
	Tb3	0.165	19.069	22	0.867
	Tb4	0.126	19.992	22	0.909
	Tb5	0.101	20.556	22	0.934
A25	Tb1	0.234	16.774	19.5	0.860
	Tb3	0.165	17.177	19.5	0.881
	Tb4	0.126	17.989	19.5	0.922
	Tb5	0.101	18.380	19.5	0.943
A28	Tb1	0.172	15.297	17.9	0.855
	Tb3	0.122	15.856	17.9	0.886
	Tb4	0.093	16.322	17.9	0.912
	Tb5	0.074	16.902	17.9	0.944
A31	Tb1	0.172	13.118	15.6	0.841
	Tb3	0.122	13.516	15.6	0.866
	Tb4	0.093	14.082	15.6	0.903
	Tb5	0.074	14.678	15.6	0.941
A34	Tb1	0.172	11.704	14	0.827
	Tb3	0.122	11.335	14	0.801
	Tb4	0.093	12.736	14	0.900
	Tb5	0.074	13.277	14	0.938
B1	Tb1	0.148	43.885	50	0.878
	Tb3	0.104	45.147	50	0.903
	Tb4	0.079	46.169	50	0.923
	Tb5	0.064	47.379	50	0.948
B4	Tb1	0.148	40.760	46	0.886
	Tb3	0.104	41.814	46	0.909
	Tb4	0.079	42.976	46	0.934
	Tb5	0.064	43.817	46	0.953
B7	Tb1	0.116	36.976	41.5	0.891
	Tb3	0.082	37.567	41.5	0.905
	Tb4	0.062	38.678	41.5	0.932
	Tb5	0.050	39.779	41.5	0.959
B10	Tb1	0.148	34.502	41	0.842
	Tb3	0.104	36.046	41	0.879
	Tb4	0.079	36.671	41	0.894
	Tb5	0.064	37.811	41	0.922
B13	Tb1	0.116	25.001	29	0.862
	Tb3	0.082	26.011	29	0.897
	Tb4	0.062	26.573	29	0.916
	Tb5	0.050	27.490	29	0.948
B16	Tb1	0.116	30.634	35	0.875
	Tb3	0.082	31.824	35	0.909
	Tb4	0.062	32.059	35	0.916
	Tb5	0.050	33.512	35	0.957
B19	Tb1	0.116	28.850	33	0.874
	Tb3	0.082	29.065	33	0.881
	Tb4	0.062	30.581	33	0.927

Tb5	0.050	31.213	33	0.946

Test Liquid 7: Glucose Solution 65%
ρ_f =1250 kg/m3; μ=0.045 PS; Temp=298 K.

Particle ID/Tube ID	d/D	$V\times10^2$(m/s)	$V_\infty \times10^2$(m/s)	$f_w = v/V_\infty$
A1 Tb1	0.234	23.651	26.8	0.882
Tb3	0.165	24.147	26.8	0.901
Tb4	0.126	24.907	26.8	0.929
Tb5	0.101	25.679	26.8	0.958
A4 Tb1	0.234	19.733	23.1	0.854
Tb3	0.165	20.515	23.1	0.888
Tb4	0.126	21.021	23.1	0.910
Tb5	0.101	21.893	23.1	0.948
A7 Tb1	0.172	16.656	19.7	0.845
Tb3	0.122	17.212	19.7	0.874
Tb4	0.093	17.596	19.7	0.893
Tb5	0.074	18.770	19.7	0.953
A10 Tb1	0.172	14.901	18	0.828
Tb3	0.122	15.402	18	0.856
Tb4	0.093	15.878	18	0.882
Tb5	0.074	16.709	18	0.928
A13 Tb1	0.234	13.161	17	0.774
Tb3	0.165	13.768	17	0.810
Tb4	0.126	14.699	17	0.865
Tb5	0.101	15.033	17	0.884
A16 Tb1	0.172	11.488	14.2	0.809
Tb3	0.122	12.523	14.2	0.882
Tb4	0.093	12.747	14.2	0.898
Tb5	0.074	13.040	14.2	0.918
A19 Tb1	0.234	31.885	37	0.862
Tb3	0.165	33.115	37	0.895
Tb4	0.126	34.315	37	0.927
Tb5	0.101	34.877	37	0.943
A22 Tb1	0.234	28.015	33.2	0.845
Tb3	0.165	30.068	33.2	0.907
Tb4	0.126	30.390	33.2	0.917
Tb5	0.101	30.890	33.2	0.932
A25 Tb1	0.234	24.865	28.6	0.869
Tb3	0.165	25.997	28.6	0.909
Tb4	0.126	26.619	28.6	0.931
Tb5	0.101	27.004	28.6	0.944
A28 Tb1	0.172	23.963	26.4	0.908
Tb3	0.122	24.028	26.4	0.910
Tb4	0.093	24.838	26.4	0.941
Tb5	0.074	25.583	26.4	0.969
A31 Tb1	0.172	21.750	24.9	0.873
Tb3	0.122	22.220	24.9	0.892
Tb4	0.093	22.723	24.9	0.913
Tb5	0.074	23.882	24.9	0.959

A34	Tb1	0.172	19.568	21.6	0.910
	Tb3	0.122	19.947	21.6	0.928
	Tb4	0.093	20.305	21.6	0.944
	Tb5	0.074	20.884	21.6	0.971
B1	Tb1	0.148	58.815	67.5	0.871
	Tb3	0.104	60.746	67.5	0.900
	Tb4	0.079	62.579	67.5	0.927
	Tb5	0.064	64.018	67.5	0.948
B4	Tb1	0.148	52.416	58.2	0.933
	Tb3	0.104	53.850	58.2	0.958
	Tb4	0.079	54.834	58.2	0.976
	Tb5	0.064	55.962	58.2	0.996
B7	Tb1	0.116	48.966	54.5	0.903
	Tb3	0.082	50.579	54.5	0.933
	Tb4	0.062	51.221	54.5	0.945
	Tb5	0.050	52.328	54.5	0.965
B10	Tb1	0.148	43.777	53	0.826
	Tb3	0.104	44.009	53	0.830
	Tb4	0.079	44.503	53	0.840
	Tb5	0.064	45.739	53	0.863
B13	Tb1	0.116	35.978	38	0.947
	Tb3	0.082	36.234	38	0.954
	Tb4	0.062	36.923	38	0.972
	Tb5	0.050	37.391	38	0.984
B16	Tb1	0.116	45.525	50	0.910
	Tb3	0.082	46.806	50	0.936
	Tb4	0.062	47.079	50	0.942
	Tb5	0.050	48.505	50	0.970
B19	Tb1	0.116	39.393	43	0.916
	Tb3	0.082	39.928	43	0.929
	Tb4	0.062	40.518	43	0.942
	Tb5	0.050	40.970	43	0.953

Test Liquid 8: Glucose Solution 60%

ρ_f=1219 kg/m3; μ=0.02 Pa.s; Temp=298K.

Particle ID/Tube ID		d/D	$vx10^2$(m/s)	$V_\infty x10^2$(m/s)	$f_w = v/V_\infty$
A1	Tb1	0.234	24.491	29.8	0.825
	Tb3	0.165	25.734	29.8	0.866
	Tb4	0.126	26.510	29.8	0.893
	Tb5	0.101	27.801	29.8	0.936
A4	Tb1	0.234	22.197	27.8	0.801
	Tb3	0.165	23.098	27.8	0.834
	Tb4	0.126	24.729	27.8	0.893
	Tb5	0.101	25.476	27.8	0.920
A7	Tb1	0.172	19.967	24	0.832
	Tb3	0.122	20.660	24	0.861
	Tb4	0.093	21.711	24	0.905
	Tb5	0.074	22.466	24	0.936
A10	Tb1	0.172	19.032	22	0.865

	Tb3	0.122	19.272	22	0.876
	Tb4	0.093	20.014	22	0.910
	Tb5	0.074	20.998	22	0.954
A16	Tb1	0.172	16.531	20	0.827
	Tb3	0.122	17.600	20	0.880
	Tb4	0.093	18.298	20	0.915
	Tb5	0.074	18.479	20	0.924
A13	Tb1	0.234	17.705	21	0.843
	Tb3	0.165	18.462	21	0.879
	Tb4	0.126	18.967	21	0.903
	Tb5	0.101	19.771	21	0.941
A19	Tb1	0.234	34.627	39.7	0.866
	Tb3	0.165	36.165	39.7	0.904
	Tb4	0.126	36.870	39.7	0.922
	Tb5	0.101	37.581	39.7	0.940
A22	Tb1	0.234	31.289	37	0.846
	Tb3	0.165	32.711	37	0.884
	Tb4	0.126	33.918	37	0.917
	Tb5	0.101	34.668	37	0.937
A25	Tb1	0.234	29.255	34.2	0.855
	Tb3	0.165	30.669	34.2	0.897
	Tb4	0.126	31.481	34.2	0.920
	Tb5	0.101	32.178	34.2	0.941
A28	Tb1	0.172	24.269	28.3	0.858
	Tb3	0.122	25.007	28.3	0.884
	Tb4	0.093	25.930	28.3	0.916
	Tb5	0.074	26.744	28.3	0.945
A31	Tb1	0.172	22.591	26.5	0.852
	Tb3	0.122	23.449	26.5	0.885
	Tb4	0.093	24.114	26.5	0.910
	Tb5	0.074	24.997	26.5	0.943
A34	Tb1	0.172	21.101	24.8	0.851
	Tb3	0.122	21.877	24.8	0.882
	Tb4	0.093	22.336	24.8	0.901
	Tb5	0.074	23.550	24.8	0.950
B1	Tb1	0.148	65.350	74.5	0.877
	Tb3	0.104	68.477	74.5	0.919
	Tb4	0.079	69.149	74.5	0.928
	Tb5	0.064	70.770	74.5	0.950
B4	Tb1	0.148	62.009	71.3	0.870
	Tb3	0.104	64.227	71.3	0.901
	Tb4	0.079	66.464	71.3	0.932
	Tb5	0.064	67.272	71.3	0.944
B7	Tb1	0.116	60.693	66.3	0.915
	Tb3	0.082	62.205	66.3	0.938
	Tb4	0.062	62.960	66.3	0.950
	Tb5	0.050	64.193	66.3	0.968
B10	Tb1	0.148	56.550	64.5	0.884
	Tb3	0.104	57.992	64.5	0.906

Tb4	0.079	59.766	64.5	0.934
Tb5	0.064	61.437	64.5	0.960
B13 Tb1	0.116	42.246	47.9	0.882
Tb3	0.082	43.721	47.9	0.913
Tb4	0.062	44.505	47.9	0.929
Tb5	0.050	45.779	47.9	0.956
B16 Tb1	0.116	50.383	59.2	0.851
Tb3	0.082	51.877	59.2	0.876
Tb4	0.062	54.785	59.2	0.925
Tb5	0.050	55.335	59.2	0.935
B19 Tb1	0.116	45.824	53.9	0.852
Tb3	0.082	46.701	53.9	0.868
Tb4	0.062	47.975	53.9	0.892
Tb5	0.050	51.573	53.9	0.959

Test Liquid 9: Glycerin Solution 95%.

ρ_f=1225 kg/m3; μ=0.309 Pa.s; Temp=300 K.

Particle ID/Tube ID	d/D	$v\times10^2$(m/s)	$V_\infty\times10^2$(m/s)	$f_w=v/V_\infty$
A1 Tb1	0.234	8.946	13.5	0.663
Tb3	0.165	9.695	13.5	0.718
Tb4	0.126	10.901	13.5	0.807
Tb5	0.101	11.964	13.5	0.886
A4 Tb1	0.234	7.610	11	0.692
Tb3	0.165	8.357	11	0.760
Tb4	0.126	8.908	11	0.810
Tb5	0.172	4.624	6	0.771
A7 Tb1	0.122	4.965	6	0.827
Tb3	0.093	5.374	6	0.896
Tb4	0.074	5.612	6	0.935
Tb5	0.172	3.906	5	0.781
A10 Tb1	0.122	4.112	5	0.822
Tb3	0.093	4.430	5	0.886
Tb4	0.074	4.650	5	0.930
Tb5	0.101	9.648	11	0.877
A13 Tb1	0.234	2.919	4.5	0.663
Tb3	0.165	3.080	4.5	0.700
Tb4	0.126	3.663	4.5	0.833
Tb5	0.101	3.723	4.5	0.846
A16 Tb1	0.172	2.741	3.5	0.783
Tb3	0.122	2.906	3.5	0.830
Tb4	0.093	3.093	3.5	0.884
Tb5	0.074	3.289	3.5	0.940
A19 Tb1	0.234	14.679	21.5	0.683
Tb3	0.165	15.971	21.5	0.743
Tb4	0.126	17.769	21.5	0.826
Tb5	0.101	18.848	21.5	0.877
A22 Tb1	0.234	12.693	18.5	0.686
Tb3	0.165	14.402	18.5	0.778
Tb4	0.126	15.263	18.5	0.825

	Tb5	0.101	16.012	18.5	0.866
A25	Tb1	0.234	10.359	16	0.647
	Tb3	0.165	11.281	16	0.705
	Tb4	0.126	13.076	16	0.817
	Tb5	0.101	13.767	16	0.860
A28	Tb1	0.172	9.211	12.25	0.752
	Tb3	0.122	9.500	12.25	0.776
	Tb4	0.093	10.507	12.25	0.858
	Tb5	0.074	11.045	12.25	0.902
A31	Tb1	0.172	7.603	10.5	0.724
	Tb3	0.122	8.378	10.5	0.798
	Tb4	0.093	8.901	10.5	0.848
	Tb5	0.074	9.333	10.5	0.889
A34	Tb1	0.172	6.173	8.5	0.726
	Tb3	0.122	6.513	8.5	0.766
	Tb4	0.093	7.155	8.5	0.842
	Tb5	0.074	7.658	8.5	0.901
B1	Tb1	0.148	18.982	43	0.741
	Tb3	0.104	20.789	43	0.812
	Tb4	0.079	22.052	43	0.861
	Tb5	0.064	22.778	43	0.890
B4	Tb1	0.148	16.883	39	0.750
	Tb3	0.104	18.273	39	0.812
	Tb4	0.079	19.699	39	0.875
	Tb5	0.064	20.022	39	0.890
B7	Tb1	0.116	15.070	36	0.783
	Tb3	0.082	15.814	36	0.821
	Tb4	0.062	16.940	36	0.880
	Tb5	0.050	17.524	36	0.910
B10	Tb1	0.148	12.877	33.6	0.725
	Tb3	0.104	14.122	33.6	0.796
	Tb4	0.079	15.066	33.6	0.849
	Tb5	0.064	15.781	33.6	0.889
B13	Tb1	0.116	10.114	22	0.755
	Tb3	0.082	10.805	22	0.806
	Tb4	0.062	11.638	22	0.869
	Tb5	0.050	11.902	22	0.888
B16	Tb1	0.116	12.545	27	0.784
	Tb3	0.082	13.356	27	0.835
	Tb4	0.062	14.160	27	0.885
	Tb5	0.050	14.632	27	0.915
B19	Tb1	0.116	10.580	25	0.750
	Tb3	0.082	11.517	25	0.817
	Tb4	0.062	12.203	25	0.865
	Tb5	0.050	12.578	25	0.892
N1	Tb1	0.375	2.384	3.9	0.611
	Tb3	0.261	2.803	3.9	0.719
	Tb4	0.198	3.100	3.9	0.795
	Tb5	0.159	3.291	3.9	0.844

N4	Tb1	0.250	1.736	2.8	0.599
	Tb3	0.174	1.935	2.8	0.667
	Tb4	0.132	2.207	2.8	0.761
	Tb5	0.106	2.497	2.8	0.861

Test Liquid 11: Castor Oil

ρ_f =955 kg/m3; μ=0.473 PS; Temp=308 K.

Particle ID/Tube ID		d/D	$vx10^2$(m/s)	$V_\infty x10^2$(m/s)	$f_w = v/V_\infty$
P1	Tb1	0.370	0.039	0.06	0.650
	Tb2	0.296	0.044	0.06	0.730
	Tb3	0.257	0.046	0.06	0.763
	Tb4	0.196	0.047	0.06	0.790
	Tb5	0.157	0.052	0.06	0.872
P4	Tb1	0.368	0.042	0.068	0.622
	Tb2	0.294	0.047	0.068	0.698
	Tb3	0.256	0.050	0.068	0.739
	Tb4	0.195	0.055	0.068	0.803
	Tb5	0.156	0.056	0.068	0.828
P7	Tb1	0.375	0.034	0.053	0.642
	Tb2	0.300	0.040	0.053	0.748
	Tb3	0.261	0.042	0.053	0.786
	Tb4	0.198	0.042	0.053	0.796
	Tb5	0.159	0.045	0.053	0.853
P10	Tb1	0.365	0.028	0.048	0.591
	Tb2	0.292	0.032	0.048	0.673
	Tb3	0.254	0.036	0.048	0.746
	Tb4	0.193	0.038	0.048	0.784
	Tb5	0.155	0.038	0.048	0.797
P13	Tb1	0.375	0.019	0.035	0.547
	Tb2	0.300	0.024	0.035	0.679
	Tb3	0.261	0.025	0.035	0.700
	Tb4	0.198	0.026	0.035	0.740
	Tb5	0.159	0.028	0.035	0.812
P16	Tb1	0.375	0.015	0.027	0.545
	Tb2	0.300	0.016	0.027	0.608
	Tb3	0.261	0.019	0.027	0.701
	Tb4	0.198	0.020	0.027	0.751
	Tb5	0.159	0.022	0.027	0.797
P19	Tb1	0.375	0.007	0.013	0.549
	Tb2	0.300	0.007	0.013	0.574
	Tb3	0.261	0.009	0.013	0.683
	Tb4	0.198	0.011	0.013	0.832
	Tb5	0.159	0.011	0.013	0.851
P22	Tb1	0.250	0.022	0.036	0.688
	Tb2	0.200	0.024	0.036	0.756
	Tb3	0.174	0.026	0.036	0.814
	Tb4	0.132	0.027	0.036	0.836

	Tb5	0.106	0.027	0.036	0.850
P25	Tb1	0.250	0.021	0.03	0.710
	Tb2	0.200	0.023	0.03	0.757
	Tb3	0.174	0.025	0.03	0.818
	Tb4	0.132	0.025	0.03	0.849
	Tb5	0.106	0.027	0.03	0.884
P28	Tb1	0.250	0.014	0.022	0.643
	Tb2	0.200	0.016	0.022	0.721
	Tb3	0.174	0.016	0.022	0.706
	Tb4	0.132	0.018	0.022	0.808
	Tb5	0.106	0.019	0.022	0.877
P31	Tb1	0.250	0.012	0.017	0.729
	Tb2	0.200	0.013	0.017	0.777
	Tb3	0.174	0.013	0.017	0.758
	Tb4	0.132	0.014	0.017	0.837
	Tb5	0.106	0.015	0.017	0.907
P34	Tb1	0.250	0.006	0.01	0.670
	Tb2	0.200	0.007	0.01	0.718
	Tb3	0.174	0.007	0.01	0.739
	Tb4	0.132	0.008	0.01	0.843
	Tb5	0.106	0.008	0.01	0.850
N1	Tb1	0.375	0.062	0.102	0.611
	Tb2	0.300	0.067	0.102	0.657
	Tb3	0.261	0.072	0.102	0.707
	Tb4	0.198	0.079	0.102	0.770
	Tb5	0.159	0.087	0.102	0.852
N4	Tb3	0.250	0.040	0.06	0.660
	Tb2	0.200	0.043	0.06	0.720
	Tb3	0.174	0.046	0.06	0.765
	Tb4	0.132	0.049	0.06	0.810
	Tb5	0.106	0.050	0.06	0.835
B1	Tb1	0.148	0.243	0.3	0.761
	Tb2	0.119	0.254	0.3	0.795
	Tb3	0.104	0.262	0.3	0.820
	Tb4	0.079	0.271	0.3	0.848
	Tb5	0.064	0.272	0.3	0.851
B4	Tb1	0.148	0.210	0.285	0.750
	Tb2	0.119	0.228	0.285	0.815
	Tb3	0.104	0.231	0.285	0.824
	Tb4	0.079	0.236	0.285	0.845
	Tb5	0.064	0.248	0.285	0.991
B7	Tb1	0.116	0.200	0.25	0.799
	Tb2	0.093	0.207	0.25	0.827
	Tb3	0.082	0.207	0.25	0.829
	Tb4	0.062	0.217	0.25	0.868
	Tb5	0.050	0.236	0.25	0.942
B10	Tb1	0.148	0.173	0.24	0.751
	Tb2	0.119	0.187	0.24	0.812
	Tb3	0.104	0.190	0.24	0.827

	Tb4	0.079	0.194	0.24	0.844
	Tb5	0.064	0.214	0.24	0.930
B13	Tb1	0.148	0.111	0.14	0.790
	Tb2	0.119	0.116	0.14	0.825
	Tb3	0.104	0.121	0.14	0.861
	Tb4	0.079	0.128	0.14	0.913
	Tb5	0.064	0.131	0.14	0.935
B16	Tb1	0.116	0.151	0.19	0.794
	Tb2	0.093	0.159	0.19	0.835
	Tb3	0.082	0.163	0.19	0.856
	Tb4	0.062	0.171	0.19	0.900
	Tb5	0.050	0.174	0.19	0.916
B19	Tb1	0.116	0.130	0.165	0.787
	Tb2	0.093	0.136	0.165	0.825
	Tb3	0.082	0.141	0.165	0.854
	Tb4	0.062	0.147	0.165	0.894
	Tb5	0.050	0.150	0.165	0.907
Ba	Tb1	0.116	0.100	0.128	0.781
	Tb2	0.093	0.107	0.128	0.834
	Tb3	0.082	0.109	0.128	0.854
	Tb4	0.062	0.113	0.128	0.885
	Tb5	0.050	0.116	0.128	0.910

Test Liquid 10: Silicone Oil

ρ_f =975 kg/m3; μ=0.26 Pa.s; Temp=308 K.

Particle ID	Tube ID	d/D	$v \times 10^2$(m/s)	$V_\infty \times 10^2$(m/s)	$f_w = v/V_\infty$
P1	Tb1	0.370	0.047	0.074	0.640
	Tb2	0.296	0.054	0.074	0.724
	Tb3	0.257	0.056	0.074	0.755
	Tb4	0.196	0.060	0.074	0.809
	Tb5	0.157	0.063	0.074	0.846
P4	Tb1	0.368	0.057	0.088	0.647
	Tb2	0.294	0.067	0.088	0.758
	Tb3	0.256	0.070	0.088	0.791
	Tb4	0.195	0.072	0.088	0.818
	Tb5	0.156	0.075	0.088	0.847
P7	Tb1	0.375	0.035	0.06	0.580
	Tb2	0.300	0.040	0.06	0.672
	Tb3	0.261	0.044	0.06	0.732
	Tb4	0.198	0.045	0.06	0.747
	Tb5	0.159	0.050	0.06	0.834
P10	Tb1	0.365	0.032	0.0578	0.547
	Tb2	0.292	0.038	0.0578	0.649
	Tb3	0.254	0.040	0.0578	0.690
	Tb4	0.193	0.043	0.0578	0.746
	Tb5	0.155	0.047	0.0578	0.818
P13	Tb1	0.375	0.026	0.046	0.564
	Tb2	0.300	0.031	0.046	0.664
	Tb3	0.261	0.032	0.046	0.696

	Tb4	0.198	0.036	0.046	0.777
	Tb5	0.159	0.037	0.046	0.809
P16	Tb1	0.375	0.019	0.0338	0.549
	Tb2	0.300	0.020	0.0338	0.600
	Tb3	0.261	0.023	0.0338	0.674
	Tb4	0.198	0.026	0.0338	0.755
	Tb5	0.159	0.027	0.0338	0.810
P19	Tb1	0.375	0.011	0.0196	0.560
	Tb2	0.300	0.012	0.0196	0.587
	Tb3	0.261	0.013	0.0196	0.680
	Tb4	0.198	0.015	0.0196	0.771
	Tb5	0.159	0.016	0.0196	0.806
P22	Tb1	0.250	0.039	0.0505	0.765
	Tb2	0.200	0.040	0.0505	0.792
	Tb3	0.174	0.043	0.0505	0.849
	Tb4	0.132	0.045	0.0505	0.882
	Tb5	0.106	0.045	0.0505	0.892
P25	Tb1	0.250	0.034	0.0463	0.745
	Tb2	0.200	0.037	0.0463	0.801
	Tb3	0.174	0.039	0.0463	0.840
	Tb4	0.132	0.040	0.0463	0.868
	Tb5	0.106	0.041	0.0463	0.889
P28	Tb1	0.250	0.020	0.032	0.658
	Tb2	0.200	0.024	0.032	0.769
	Tb3	0.174	0.024	0.032	0.760
	Tb4	0.132	0.025	0.032	0.806
	Tb5	0.106	0.028	0.032	0.891
P31	Tb1	0.250	0.017	0.025	0.669
	Tb2	0.200	0.018	0.025	0.729
	Tb3	0.174	0.020	0.025	0.779
	Tb4	0.132	0.020	0.025	0.800
	Tb5	0.106	0.022	0.025	0.873
P34	Tb1	0.250	0.010	0.014	0.684
	Tb2	0.200	0.010	0.014	0.713
	Tb3	0.174	0.011	0.014	0.772
	Tb4	0.132	0.011	0.014	0.794
	Tb5	0.106	0.012	0.014	0.880
N1	Tb1	0.375	0.089	0.14	0.636
	Tb2	0.300	0.096	0.14	0.689
	Tb3	0.261	0.103	0.14	0.736
	Tb4	0.198	0.110	0.14	0.785
	Tb5	0.159	0.120	0.14	0.859
N4	Tb3	0.250	0.053	0.078	0.673
	Tb2	0.200	0.058	0.078	0.747
	Tb3	0.174	0.059	0.078	0.761
	Tb4	0.132	0.062	0.078	0.800
	Tb5	0.106	0.064	0.078	0.823
B1	Tb1	0.148	0.318	0.42	0.758
	Tb2	0.119	0.340	0.42	0.810

	Tb3	0.104	0.350	0.42	0.833
	Tb4	0.079	0.363	0.42	0.865
	Tb5	0.064	0.371	0.42	0.883
B4	Tb1	0.148	0.272	0.355	0.766
	Tb2	0.119	0.282	0.355	0.793
	Tb3	0.104	0.288	0.355	0.810
	Tb4	0.079	0.305	0.355	0.858
	Tb5	0.064	0.325	0.355	0.915
B7	Tb1	0.116	0.259	0.32	0.808
	Tb2	0.093	0.264	0.32	0.825
	Tb3	0.082	0.267	0.32	0.834
	Tb4	0.062	0.275	0.32	0.859
	Tb5	0.050	0.287	0.32	0.896
B10	Tb1	0.148	0.235	0.3	0.784
	Tb2	0.119	0.248	0.3	0.825
	Tb3	0.104	0.249	0.3	0.831
	Tb4	0.079	0.261	0.3	0.869
	Tb5	0.064	0.274	0.3	0.912
B13	Tb1	0.148	0.179	0.237	0.755
	Tb2	0.119	0.183	0.237	0.771
	Tb3	0.104	0.193	0.237	0.813
	Tb4	0.079	0.202	0.237	0.852
	Tb5	0.064	0.208	0.237	0.878
B16	Tb1	0.116	0.201	0.2275	0.883
	Tb2	0.093	0.212	0.2275	0.930
	Tb3	0.082	0.215	0.2275	0.946
	Tb4	0.062	0.218	0.2275	0.959
	Tb5	0.050	0.229	0.2275	1.007
B19	Tb1	0.116	0.177	0.225	0.788
	Tb2	0.093	0.186	0.225	0.826
	Tb3	0.082	0.193	0.225	0.858
	Tb4	0.062	0.196	0.225	0.870
	Tb5	0.050	0.200	0.225	0.891
Ba	Tb1	0.116	0.158	0.173	0.915
	Tb2	0.093	0.161	0.173	0.929
	Tb3	0.082	0.163	0.173	0.941
	Tb4	0.062	0.164	0.173	0.950
	Tb5	0.050	0.167	0.173	0.965

Non-Newtonian Media

I. SPHERE

Test Liquid 14: CMC 0.75%
Density, ρ_f=1000 kg/m^3; n=0.591; k=0.529(P.S^n); Temp=291K

Particle ID	Tube ID	d/D	$v \times 10^2$(m/s)	$V_\infty \times 10^2$ (m/s)	$f_w = v/V_\infty$
S6	Tb1	0.144	78.748	87	0.905
	Tb3	0.102	79.993	87	0.919
	Tb4	0.077	80.852	87	0.929
	Tb5	0.062	84.218	87	0.968
S8	Tb1	0.194	97.444	100	0.974
	Tb3	0.137	98.151	100	0.982
	Tb4	0.104	99.019	100	0.990
	Tb5	0.083	99.336	100	0.993
S10	Tb1	0.258	115.802	135	0.858
	Tb3	0.182	119.762	135	0.887
	Tb4	0.139	124.660	135	0.923
	Tb5	0.111	126.999	135	0.941
S12	Tb1	0.312	126.833	149	0.851
	Tb3	0.220	134.477	149	0.903
	Tb4	0.167	135.728	149	0.911
	Tb5	0.134	139.878	149	0.939
G_GB	Tb1	0.505	58.673	76	0.772
	Tb3	0.357	62.417	76	0.821
	Tb4	0.271	65.926	76	0.867
	Tb5	0.217	69.658	76	0.917
G_G	Tb1	0.493	55.269	73	0.757
	Tb3	0.348	59.069	73	0.809
	Tb4	0.265	62.011	73	0.849
	Tb5	0.212	66.575	73	0.912
G_S	Tb1	0.312	34.937	45	0.776
	Tb3	0.221	37.833	45	0.841
	Tb4	0.168	38.658	45	0.859
	Tb5	0.134	41.525	45	0.923
G_VS	Tb1	0.308	34.403	41	0.839
	Tb3	0.217	36.092	41	0.880
	Tb4	0.165	38.051	41	0.928
	Tb5	0.132	38.142	41	0.930
T6	Tb1	0.148	11.157	15	0.744
	Tb3	0.104	11.765	15	0.784
	Tb4	0.079	12.753	15	0.850
	Tb5	0.064	13.569	15	0.905
T8	Tb1	0.197	17.691	22	0.804
	Tb3	0.139	18.566	22	0.844
	Tb4	0.106	19.564	22	0.889
	Tb5	0.084	20.478	22	0.931
T10	Tb1	0.246	24.111	29.5	0.817
	Tb3	0.174	25.051	29.5	0.849
	Tb4	0.132	26.421	29.5	0.896
	Tb5	0.106	27.326	29.5	0.926

Test Liquid 15: CMC 0.6%

Density, ρ_f =1000 kg/m^3; n=0.623; k=0.292 (P.S^n); Temp=291K

Particle ID/Tube ID		d/D	vx10^2(m/s)	V_∞x10^2 (m/s)	f_w=v/V_∞
S6	Tb1	0.148	92.067	107	0.860
	Tb3	0.104	95.067	107	0.888
	Tb4	0.079	99.444	107	0.929
	Tb5	0.064	101.545	107	0.949
S8	Tb1	0.197	103.773	127	0.817
	Tb3	0.139	107.446	127	0.846
	Tb4	0.106	114.261	127	0.900
	Tb5	0.084	117.557	127	0.926
S10	Tb1	0.246	112.775	142	0.794
	Tb3	0.174	118.925	142	0.837
	Tb4	0.132	125.952	142	0.887
	Tb5	0.106	130.221	142	0.917
S12	Tb1	0.296	118.211	152	0.778
	Tb3	0.209	126.508	152	0.832
	Tb4	0.159	132.104	152	0.869
	Tb5	0.127	138.326	152	0.910
G_S	Tb1	0.312	55.244	74	0.747
	Tb3	0.221	60.304	74	0.815
	Tb4	0.168	63.671	74	0.860
	Tb5	0.134	65.221	74	0.881
G_GB	Tb1	0.505	57.915	95	0.610
	Tb3	0.357	69.210	95	0.729
	Tb4	0.271	75.338	95	0.793
	Tb5	0.217	78.554	95	0.827
G_G	Tb1	0.493	55.579	90	0.618
	Tb3	0.348	62.010	90	0.689
	Tb4	0.265	70.847	90	0.787
	Tb5	0.212	75.448	90	0.838
G_VS	Tb1	0.308	50.162	67.5	0.743
	Tb3	0.217	55.569	67.5	0.823
	Tb4	0.165	57.799	67.5	0.856
	Tb5	0.132	60.146	67.5	0.891
T6	Tb1	0.148	19.911	22	0.905
	Tb3	0.104	20.419	22	0.928
	Tb4	0.079	20.775	22	0.944
	Tb5	0.064	21.441	22	0.975
T8	Tb1	0.197	29.140	34.5	0.845
	Tb3	0.139	29.344	34.5	0.851
	Tb4	0.106	31.163	34.5	0.903
	Tb5	0.084	32.659	34.5	0.947
T10	Tb1	0.246	37.931	45	0.843
	Tb3	0.174	39.097	45	0.869
	Tb4	0.132	40.879	45	0.908
	Tb5	0.106	42.222	45	0.938

Test Liquid 16: CMC 0.5%

Density, ρ_f =1000 kg/m^3; n=0.617; k=0.261(P.S^n); Temp=292K

Particle ID/Tube ID		d/D	vx10^2(m/s)	V_∞x10^2 (m/s)	f_w=v/V_∞
S6	Tb1	0.148	113.995	122	0.934
	Tb3	0.104	115.995	122	0.951
	Tb4	0.079	119.229	122	0.977

	Tb5	0.064	121.333	122	0.995
S8	Tb1	0.197	120.638	140	0.862
	Tb3	0.139	124.638	140	0.890
	Tb4	0.106	130.241	140	0.930
	Tb5	0.084	132.351	140	0.945
S10	Tb1	0.246	135.386	160	0.846
	Tb3	0.174	142.386	160	0.890
	Tb4	0.132	146.776	160	0.917
	Tb5	0.106	149.746	160	0.936
S12	Tb1	0.296	153.679	177	0.868
	Tb3	0.209	158.668	177	0.896
	Tb4	0.159	161.402	177	0.912
	Tb5	0.127	168.663	177	0.953
G_G	Tb1	0.493	76.450	100	0.765
	Tb3	0.348	80.224	100	0.802
	Tb4	0.265	87.312	100	0.873
	Tb5	0.212	89.632	100	0.896
G_GB	Tb1	0.505	60.489	91	0.665
	Tb3	0.357	68.704	91	0.755
	Tb4	0.271	72.315	91	0.795
	Tb5	0.217	79.676	91	0.876
G_S	Tb1	0.312	49.966	55	0.908
	Tb3	0.221	51.562	55	0.937
	Tb4	0.168	52.376	55	0.952
	Tb5	0.134	52.932	55	0.962
G_VS	Tb1	0.308	47.327	51	0.928
	Tb3	0.217	48.470	51	0.950
	Tb4	0.165	49.253	51	0.966
	Tb5	0.132	50.010	51	0.981
T6	Tb1	0.148	25.394	29	0.876
	Tb3	0.104	25.802	29	0.890
	Tb4	0.079	26.778	29	0.923
	Tb5	0.064	27.428	29	0.946
T8	Tb1	0.197	34.561	39	0.886
	Tb3	0.139	35.778	39	0.917
	Tb4	0.106	36.356	39	0.932
	Tb5	0.084	37.033	39	0.950
T10	Tb1	0.246	44.184	53.8	0.821
	Tb3	0.174	45.693	53.8	0.849
	Tb4	0.132	47.974	53.8	0.892
	Tb5	0.106	49.785	53.8	0.925

Test Liquid 17: CMC 0.4%

Density, ρ_f=1000 kg/m^3; n=0.669; k=0.231(P.S^n); Temp=293K

Particle ID/Tube ID		d/D	vx10^2(m/s)	V_∞x10^2 (m/s)	f_w=v/V_∞
S6	Tb1	0.144	100.593	118	0.852
	Tb3	0.102	102.807	118	0.871
	Tb4	0.077	108.597	118	0.920
	Tb5	0.062	110.245	118	0.934
S8	Tb1	0.194	110.453	133	0.830
	Tb3	0.137	115.633	133	0.869
	Tb4	0.104	119.605	133	0.899
	Tb5	0.083	124.567	133	0.937
S10	Tb1	0.258	129.447	154	0.841
	Tb3	0.182	133.659	154	0.868

	Tb4	0.139	139.387	154	0.905
	Tb5	0.111	143.987	154	0.935
S12	Tb1	0.312	168.582	221	0.763
	Tb3	0.220	179.321	221	0.811
	Tb4	0.167	190.555	221	0.862
	Tb5	0.134	201.495	221	0.912
G_GB	Tb1	0.505	58.673	76	0.772
	Tb3	0.357	62.417	76	0.821
	Tb4	0.271	65.926	76	0.867
	Tb5	0.217	69.658	76	0.917
G_G	Tb1	0.493	55.269	73	0.757
	Tb3	0.348	59.069	73	0.809
	Tb4	0.265	62.011	73	0.849
	Tb5	0.212	66.575	73	0.912
G_S	Tb1	0.312	50.389	55	0.916
	Tb3	0.221	51.833	55	0.942
	Tb4	0.168	52.658	55	0.957
	Tb5	0.134	53.025	55	0.964
G_VS	Tb1	0.308	45.303	50	0.906
	Tb3	0.217	47.092	50	0.942
	Tb4	0.165	48.051	50	0.961
	Tb5	0.132	48.142	50	0.963
T6	Tb1	0.148	23.172	24.5	0.946
	Tb3	0.104	23.446	24.5	0.957
	Tb4	0.079	23.602	24.5	0.963
	Tb5	0.064	24.072	24.5	0.983
T8	Tb1	0.197	31.219	33.5	0.932
	Tb3	0.139	31.546	33.5	0.942
	Tb4	0.106	31.965	33.5	0.954
	Tb5	0.084	32.612	33.5	0.974
T10	Tb1	0.246	40.002	46.8	0.855
	Tb3	0.174	43.241	46.8	0.924
	Tb4	0.132	43.292	46.8	0.925
	Tb5	0.106	43.589	46.8	0.931

Test Liquid 18: Methocel 1.2%
Density, ρ_f =1000 kg/m^3; n=0.698; k=2.069(P.S^n); Temp=296K

Particle ID/Tube ID		d/D	vx10^2(m/s)	V_∞x10^2 (m/s)	f_w=v/V_∞
S6	Tb1	0.144	13.531	16	0.846
	Tb3	0.102	14.005	16	0.875
	Tb4	0.077	14.706	16	0.919
	Tb5	0.062	15.232	16	0.952
S8	Tb1	0.194	20.003	27	0.741
	Tb3	0.137	21.085	27	0.781
	Tb4	0.104	23.312	27	0.863
	Tb5	0.083	24.397	27	0.904
S10	Tb1	0.258	28.297	38	0.745
	Tb3	0.182	30.789	38	0.810
	Tb4	0.139	32.275	38	0.849
	Tb5	0.111	34.163	38	0.899
S12	Tb1	0.312	39.560	55	0.719
	Tb3	0.220	44.520	55	0.809
	Tb4	0.167	45.285	55	0.823
	Tb5	0.134	49.758	55	0.905
S14	Tb1	0.331	49.702	68	0.731

	Tb3	0.234	54.780	68	0.806
	Tb4	0.178	57.372	68	0.844
	Tb5	0.142	58.901	68	0.866
G_GB	Tb1	0.505	12.570	26	0.483
	Tb3	0.357	15.951	26	0.613
	Tb4	0.271	18.010	26	0.693
	Tb5	0.217	21.021	26	0.809
G_G	Tb1	0.493	11.750	22	0.534
	Tb3	0.348	14.199	22	0.645
	Tb4	0.265	17.104	22	0.777
	Tb5	0.212	18.768	22	0.853
G_S	Tb1	0.312	6.288	12	0.524
	Tb3	0.221	8.105	12	0.675
	Tb4	0.168	8.873	12	0.739
	Tb5	0.134	9.039	12	0.753

Test Liquid 19: Methocel 1.0%

Density, ρ_f =1000 kg/m^3; n=0.720; k=1.074(P.S^n); Temp=296K

Particle ID/Tube ID		d/D	vx102(m/s)	V∞x102 (m/s)	fw=v/V∞
S6	Tb1	0.144	26.412	31	0.852
	Tb3	0.102	27.001	31	0.871
	Tb4	0.077	28.046	31	0.905
	Tb5	0.062	29.081	31	0.938
S8	Tb1	0.194	30.575	36	0.849
	Tb3	0.137	31.767	36	0.882
	Tb4	0.104	32.361	36	0.899
	Tb5	0.083	34.206	36	0.950
S10	Tb1	0.258	39.635	50	0.793
	Tb3	0.182	42.407	50	0.848
	Tb4	0.139	44.134	50	0.883
	Tb5	0.111	45.881	50	0.918
S12	Tb1	0.312	49.839	64	0.779
	Tb3	0.220	52.393	64	0.819
	Tb4	0.167	55.471	64	0.867
	Tb5	0.134	58.484	64	0.914
S14	Tb1	0.331	57.021	79	0.722
	Tb3	0.234	62.106	79	0.786
	Tb4	0.178	64.844	79	0.821
	Tb5	0.142	70.840	79	0.897
G_S	Tb1	0.312	13.357	18	0.742
	Tb3	0.221	13.835	18	0.769
	Tb4	0.168	15.175	18	0.843
	Tb5	0.134	16.205	18	0.900

Test Liquid 20: Methocel 0.75%

Density, ρ_f =1000 kg/m^3; n=0.663; k=1.003(P.S^n); Temp=288K

Particle ID/Tube ID		d/D	vx10^2(m/s)	V_∞x10^2 (m/s)	f_w=v/V_∞
S6	Tb1	0.148	39.817	50	0.796
	Tb3	0.104	41.407	50	0.828
	Tb4	0.079	43.829	50	0.877
	Tb5	0.064	45.987	50	0.920
S8	Tb1	0.197	42.205	60	0.703
	Tb3	0.139	46.970	60	0.783
	Tb4	0.106	49.593	60	0.827

	Tb5	0.084	52.245	60	0.871
S10	Tb1	0.246	52.732	70	0.753
	Tb3	0.174	56.673	70	0.810
	Tb4	0.132	59.489	70	0.850
	Tb5	0.106	63.245	70	0.904
S12	Tb1	0.296	62.541	81	0.772
	Tb3	0.209	65.233	81	0.805
	Tb4	0.159	69.841	81	0.862
	Tb5	0.127	74.145	81	0.915
G_G	Tb1	0.493	31.570	55	0.574
	Tb3	0.348	37.978	55	0.691
	Tb4	0.265	41.123	55	0.748
	Tb5	0.212	44.475	55	0.809
G_GB	Tb1	0.505	34.187	59	0.579
	Tb3	0.357	36.813	59	0.624
	Tb4	0.271	43.123	59	0.731
	Tb5	0.217	47.246	59	0.801
G_S	Tb1	0.312	25.897	35	0.740
	Tb3	0.221	27.672	35	0.791
	Tb4	0.168	30.048	35	0.859
	Tb5	0.134	32.079	35	0.917
G_VS	Tb1	0.308	23.041	28	0.823
	Tb3	0.217	23.633	28	0.844
	Tb4	0.165	24.615	28	0.879
	Tb5	0.132	25.394	28	0.907

Test Liquid 20: Methocel 0.65%

Density, ρ_f=1000 kg/m^3; n=0.689; k=0.662(P.S^n); Temp=289K

Particle ID/Tube ID		d/D	vx10^2(m/s)	V$_\infty$x10^2 (m/s)	f_w=v/V$_\infty$
T6	Tb1	0.148	8.607	10	0.861
	Tb3	0.104	8.728	10	0.873
	Tb4	0.079	9.228	10	0.923
	Tb5	0.064	9.585	10	0.959
T8	Tb1	0.197	13.110	16	0.819
	Tb3	0.139	13.362	16	0.835
	Tb4	0.106	14.176	16	0.886
	Tb5	0.084	14.909	16	0.932
T10	Tb1	0.246	17.913	22.5	0.796
	Tb3	0.174	19.399	22.5	0.862
	Tb4	0.132	19.553	22.5	0.869
	Tb5	0.106	20.741	22.5	0.922
S6	Tb1	0.148	56.218	61	0.922
	Tb3	0.104	57.968	61	0.950
	Tb4	0.079	58.596	61	0.961
	Tb5	0.064	60.302	61	0.989
S8	Tb1	0.197	81.378	89	0.914
	Tb3	0.139	83.624	89	0.940
	Tb4	0.106	84.679	89	0.951
	Tb5	0.084	85.044	89	0.956
S10	Tb1	0.246	99.004	118	0.839
	Tb3	0.174	102.202	118	0.866
	Tb4	0.132	106.879	118	0.906
	Tb5	0.106	110.559	118	0.937
S12	Tb1	0.296	134.242	157	0.855
	Tb3	0.209	139.061	157	0.886

	Tb4	0.159	144.131	157	0.918
	Tb5	0.127	147.947	157	0.942
G_S	Tb1	0.312	42.491	50	0.850
	Tb3	0.221	44.782	50	0.896
	Tb4	0.168	46.697	50	0.934
	Tb5	0.134	47.391	50	0.948
G_GB	Tb1	0.505	47.560	80	0.595
	Tb3	0.357	58.205	80	0.728
	Tb4	0.271	60.868	80	0.761
	Tb5	0.217	62.591	80	0.782
G_G	Tb1	0.493	46.750	77	0.607
	Tb3	0.348	51.198	77	0.665
	Tb4	0.265	57.256	77	0.744
	Tb5	0.212	61.606	77	0.800
G_VS	Tb1	0.308	29.478	38	0.776
	Tb3	0.217	30.064	38	0.791
	Tb4	0.165	31.964	38	0.841
	Tb5	0.132	34.821	38	0.916

II. CONES

Test Liquid 12: CMC 1.5%
Density, ρ_f =1000 kg/m^3; n=0.403; k=6.883(P.S^n); Temp=300K

Particle ID/Tube ID		d/D	vx10^2(m/s)	V_∞x10^2 (m/s)	f_w=v/V_∞
P1	Tb1	0.369	0.119	0.252	0.450
	Tb3	0.261	0.158	0.252	0.575
	Tb4	0.198	0.178	0.252	0.648
	Tb5	0.159	0.197	0.252	0.717
P4	Tb1	0.369	0.133	0.275	0.485
	Tb3	0.261	0.175	0.275	0.636
	Tb4	0.198	0.200	0.275	0.726
	Tb5	0.159	0.214	0.275	0.779
P7	Tb1	0.369	0.110	0.248	0.445
	Tb3	0.261	0.147	0.248	0.592
	Tb4	0.198	0.170	0.248	0.685
	Tb5	0.159	0.190	0.248	0.766
P10	Tb1	0.369	0.105	0.235	0.437
	Tb3	0.261	0.140	0.235	0.596
	Tb4	0.198	0.166	0.235	0.706
	Tb5	0.159	0.179	0.235	0.764
P13	Tb1	0.369	0.071	0.159	0.445
	Tb3	0.261	0.103	0.159	0.648
	Tb4	0.198	0.120	0.159	0.755
	Tb5	0.159	0.129	0.159	0.811
P22	Tb1	0.246	0.098	1.48	0.662
	Tb3	0.174	0.118	1.48	0.799
	Tb4	0.132	0.128	1.48	0.867
	Tb5	0.106	0.131	1.48	0.884
P25	Tb1	0.246	0.080	0.13	0.605
	Tb3	0.174	0.094	0.13	0.715
	Tb4	0.132	0.105	0.13	0.795
	Tb5	0.106	0.110	0.13	0.834
P28	Tb1	0.246	0.068	0.11	0.620
	Tb3	0.174	0.078	0.11	0.707
	Tb4	0.132	0.086	0.11	0.780

	Tb5	0.106	0.093	0.11	0.845
A1	Tb1	0.234	1.224	1.72	0.688
	Tb3	0.165	1.350	0.172	0.758
	Tb4	0.126	1.458	1.72	0.819
	Tb5	0.101	1.512	1.72	0.850
A4	Tb1	0.234	0.817	1.38	0.592
	Tb3	0.165	0.948	1.38	0.687
	Tb4	0.126	1.059	1.38	0.767
	Tb5	0.101	1.138	1.38	0.825
A19	Tb1	0.234	2.182	3.25	0.669
	Tb3	0.165	2.619	3.25	0.803
	Tb4	0.126	2.804	3.25	0.860
	Tb5	0.101	2.946	3.25	0.904
A22	Tb1	0.234	1.987	2.8	0.685
	Tb3	0.165	2.199	2.8	0.758
	Tb4	0.126	2.272	2.8	0.783
	Tb5	0.101	2.503	2.8	0.863
A25	Tb1	0.234	1.453	2.25	0.640
	Tb3	0.165	1.701	2.25	0.749
	Tb4	0.126	1.892	2.25	0.834
	Tb5	0.101	2.012	2.25	0.886
A28	Tb1	0.172	1.111	1.5	0.740
	Tb3	0.122	1.240	1.5	0.827
	Tb4	0.093	1.284	1.5	0.856
	Tb5	0.074	1.333	1.5	0.889
A31	Tb1	0.172	0.843	1.1	0.766
	Tb3	0.122	0.893	1.1	0.812
	Tb4	0.093	0.936	1.1	0.850
	Tb5	0.074	0.944	1.1	0.858
A34	Tb1	0.172	0.738	0.84	0.786
	Tb3	0.122	0.791	0.84	0.842
	Tb4	0.093	0.797	0.84	0.848
	Tb5	0.074	0.831	0.84	0.884
A7	Tb1	0.172	0.562	0.71	0.780
	Tb3	0.122	0.620	0.71	0.862
	Tb4	0.093	0.637	0.71	0.885
	Tb5	0.074	0.656	0.71	0.911
A10	Tb1	0.172	0.504	0.62	0.787
	Tb3	0.122	0.554	0.62	0.866
	Tb4	0.093	0.561	0.62	0.877
	Tb5	0.074	0.576	0.62	0.900
B1	Tb1	0.148	15.029	17	0.884
	Tb3	0.104	15.814	17	0.930
	Tb4	0.079	16.333	17	0.961
	Tb5	0.064	16.503	17	0.971
B4	Tb1	0.148	12.525	15.3	0.835
	Tb3	0.104	13.025	15.3	0.868
	Tb4	0.079	13.076	15.3	0.872
	Tb5	0.064	14.714	15.3	0.981
B7	Tb1	0.116	8.045	10.5	0.766
	Tb3	0.082	8.495	10.5	0.809
	Tb4	0.062	9.037	10.5	0.861
	Tb5	0.050	9.564	10.5	0.911
B10	Tb1	0.148	7.254	9.75	0.744
	Tb3	0.104	7.533	9.75	0.773
	Tb4	0.079	7.587	9.75	0.778

	Tb5	0.064	8.167	9.75	0.838
B13	Tb1	0.116	6.803	9.2	0.739
	Tb3	0.082	7.601	9.2	0.826
	Tb4	0.062	7.896	9.2	0.858
	Tb5	0.050	8.001	9.2	0.870
B16	Tb1	0.116	4.926	6.2	0.795
	Tb3	0.082	5.335	6.2	0.861
	Tb4	0.062	5.333	6.2	0.860
	Tb5	0.050	5.550	6.2	0.895

Test Liquid 13: CMC 1.3%

Density, ρ_f =1000 kg/m^3; n=0.497; k=2.166(P.S^n); Temp=291K

Particle ID/Tube ID		d/D	Vx10^2(m/s)	V_∞x10^2(m/s)	$f_w=v/V_\infty$
P1	Tb1	0.369	0.390	1.04	0.375
	Tb3	0.261	0.581	1.04	0.559
	Tb4	0.198	0.695	1.04	0.668
	Tb5	0.159	0.752	1.04	0.723
P4	Tb1	0.369	0.464	1.15	0.403
	Tb3	0.261	0.671	1.15	0.584
	Tb4	0.198	0.787	1.15	0.685
	Tb5	0.159	0.844	1.15	0.734
P7	Tb1	0.369	0.334	0.95	0.371
	Tb3	0.261	0.494	0.95	0.548
	Tb4	0.198	0.595	0.95	0.661
	Tb5	0.159	0.705	0.95	0.783
P10	Tb1	0.369	0.360	1.01	0.368
	Tb3	0.261	0.521	1.01	0.532
	Tb4	0.198	0.658	1.01	0.671
	Tb5	0.159	0.729	1.01	0.744
P13	Tb1	0.246	0.306	0.61	0.557
	Tb3	0.174	0.395	0.61	0.718
	Tb4	0.132	0.433	0.61	0.786
	Tb5	0.106	0.488	0.61	0.887
P22	Tb1	0.246	0.281	0.55	0.551
	Tb3	0.174	0.352	0.55	0.691
	Tb4	0.132	0.387	0.55	0.758
	Tb5	0.106	0.451	0.55	0.885
P25	Tb1	0.246	0.258	0.47	0.549
	Tb3	0.174	0.294	0.47	0.626
	Tb4	0.132	0.345	0.47	0.734
	Tb5	0.106	0.396	0.47	0.843
P28	Tb1	0.246	0.210	5.6	0.584
	Tb3	0.174	0.255	5.6	0.709
	Tb4	0.132	0.286	5.6	0.794
	Tb5	0.106	0.314	5.6	0.872
A1	Tb1	0.234	3.200	4.75	0.593
	Tb3	0.165	3.634	4.75	0.673
	Tb4	0.126	4.102	4.75	0.760
	Tb5	0.101	4.618	4.75	0.855
A4	Tb1	0.234	2.794	2.6	0.588
	Tb3	0.165	2.954	2.6	0.622

	Tb4	0.126	3.547	2.6	0.747
	Tb5	0.101	3.833	2.6	0.807
A19	Tb1	0.234	6.289	9.5	0.662
	Tb3	0.165	7.140	9.5	0.752
	Tb4	0.126	7.865	9.5	0.828
	Tb5	0.101	8.095	9.5	0.852
A22	Tb1	0.234	5.305	8.4	0.632
	Tb3	0.165	6.063	8.4	0.722
	Tb4	0.126	6.560	8.4	0.781
	Tb5	0.101	7.220	8.4	0.860
A25	Tb1	0.234	4.036	6.8	0.594
	Tb3	0.165	4.682	6.8	0.688
	Tb4	0.126	5.127	6.8	0.754
	Tb5	0.101	5.779	6.8	0.850
A28	Tb1	0.172	3.418	5.25	0.656
	Tb3	0.122	3.879	5.25	0.739
	Tb4	0.093	4.270	5.25	0.813
	Tb5	0.074	4.492	5.25	0.856
A31	Tb1	0.172	2.620	4.1	0.655
	Tb3	0.122	2.905	4.1	0.726
	Tb4	0.093	3.265	4.1	0.816
	Tb5	0.074	3.405	4.1	0.851
A34	Tb1	0.172	2.131	3.25	0.656
	Tb3	0.122	2.328	3.25	0.716
	Tb4	0.093	2.569	3.25	0.790
	Tb5	0.074	2.778	3.25	0.855
A7	Tb1	0.172	1.781	2.6	0.742
	Tb3	0.122	1.840	2.6	0.767
	Tb4	0.093	2.032	2.6	0.846
	Tb5	0.074	2.321	2.6	0.967
A10	Tb1	0.172	1.382	2.1	0.658
	Tb3	0.122	1.633	2.1	0.778
	Tb4	0.093	1.797	2.1	0.856
	Tb5	0.074	1.811	2.1	0.862
B1	Tb1	0.148	25.003	52.5	0.758
	Tb3	0.104	26.337	52.5	0.798
	Tb4	0.079	28.966	52.5	0.878
	Tb5	0.064	29.518	52.5	0.894
B4	Tb1	0.148	20.290	48.5	0.720
	Tb3	0.104	22.741	48.5	0.806
	Tb4	0.079	23.781	48.5	0.843
	Tb5	0.064	25.003	48.5	0.887
B7	Tb1	0.116	15.800	44.75	0.771
	Tb3	0.082	16.597	44.75	0.810
	Tb4	0.062	17.521	44.75	0.855
	Tb5	0.050	18.888	44.75	0.921
B10	Tb1	0.148	13.281	41	0.699
	Tb3	0.104	14.081	41	0.741
	Tb4	0.079	15.682	41	0.825
	Tb5	0.064	16.738	41	0.881

B13 Tb1	0.116	13.745	35	0.785
Tb3	0.082	14.424	35	0.824
Tb4	0.062	15.470	35	0.884
Tb5	0.050	15.985	35	0.913
B16 Tb1	0.116	10.053	25	0.718
Tb3	0.082	11.193	25	0.799
Tb4	0.062	11.679	25	0.834
Tb5	0.050	12.583	25	0.899

Test Liquid 14: CMC 0.75%
Density, ρ_f =1000 kg/m^3; n=0.591; k=0.529(P.S^n); Temp=291K

Particle ID/Tube ID	d/D	Vx10^2(m/s)	V_∞x10^2(m/s)	f_w=v/V_∞
P1 Tb1	0.369	5.831	7.4	0.788
Tb3	0.261	6.231	7.4	0.842
Tb4	0.198	6.499	7.4	0.878
Tb5	0.159	6.778	7.4	0.916
P4 Tb1	0.369	6.367	7.95	0.806
Tb3	0.261	6.677	7.95	0.845
Tb4	0.198	6.913	7.95	0.875
Tb5	0.159	7.352	7.95	0.931
P7 Tb1	0.369	4.802	6.6	0.728
Tb3	0.261	5.221	6.6	0.791
Tb4	0.198	5.577	6.6	0.845
Tb5	0.159	5.900	6.6	0.894
P10 Tb1	0.369	5.146	6.8	0.757
Tb3	0.261	5.547	6.8	0.816
Tb4	0.198	5.753	6.8	0.846
Tb5	0.159	6.213	6.8	0.914
P13 Tb1	0.369	4.490	6.4	0.701
Tb3	0.261	4.836	6.4	0.756
Tb4	0.198	5.323	6.4	0.832
Tb5	0.159	5.575	6.4	0.871
P22 Tb1	0.246	3.823	5.4	0.708
Tb3	0.174	4.490	5.4	0.831
Tb4	0.132	4.683	5.4	0.867
Tb5	0.106	4.981	5.4	0.922
P25 Tb1	0.246	3.139	4.7	0.713
Tb3	0.174	3.494	4.7	0.794
Tb4	0.132	3.797	4.7	0.863
Tb5	0.106	4.018	4.7	0.913
P28 Tb1	0.246	2.565	3.6	0.801
Tb3	0.174	2.692	3.6	0.841
Tb4	0.132	2.797	3.6	0.874
Tb5	0.106	2.942	3.6	0.919
A1 Tb1	0.234	21.464	25	0.859
Tb3	0.165	21.911	25	0.876
Tb4	0.126	23.142	25	0.926
Tb5	0.101	23.785	25	0.951
A4 Tb1	0.234	18.462	22.5	0.821
Tb3	0.165	19.759	22.5	0.878

	Tb4	0.126	20.381	22.5	0.906
	Tb5	0.101	21.005	22.5	0.934
A19	Tb1	0.234	34.925	43	0.812
	Tb3	0.165	37.127	43	0.863
	Tb4	0.126	38.837	43	0.903
	Tb5	0.101	39.747	43	0.924
A22	Tb1	0.234	30.699	35.5	0.865
	Tb3	0.165	31.248	35.5	0.880
	Tb4	0.126	32.778	35.5	0.923
	Tb5	0.101	33.755	35.5	0.951
A25	Tb1	0.234	25.056	30.5	0.822
	Tb3	0.165	26.550	30.5	0.870
	Tb4	0.126	27.402	30.5	0.898
	Tb5	0.101	28.148	30.5	0.923
A28	Tb1	0.172	23.045	27.5	0.838
	Tb3	0.122	24.033	27.5	0.874
	Tb4	0.093	24.970	27.5	0.908
	Tb5	0.074	25.784	27.5	0.938
A31	Tb1	0.172	20.414	24.8	0.833
	Tb3	0.122	21.122	24.8	0.862
	Tb4	0.093	21.934	24.8	0.895
	Tb5	0.074	22.892	24.8	0.934
A34	Tb1	0.172	17.036	20.7	0.831
	Tb3	0.122	17.695	20.7	0.863
	Tb4	0.093	18.382	20.7	0.897
	Tb5	0.074	19.111	20.7	0.932
A7	Tb1	0.172	14.430	18	0.802
	Tb3	0.122	15.605	18	0.867
	Tb4	0.093	16.055	18	0.892
	Tb5	0.074	16.991	18	0.944
A10	Tb1	0.172	12.057	15	0.804
	Tb3	0.122	12.929	15	0.862
	Tb4	0.093	13.260	15	0.884
	Tb5	0.074	13.815	15	0.921
B1	Tb1	0.148	70.335	87.5	0.804
	Tb3	0.104	74.623	87.5	0.853
	Tb4	0.079	77.570	87.5	0.887
	Tb5	0.064	80.315	87.5	0.918
B4	Tb1	0.148	60.081	75	0.801
	Tb3	0.104	65.403	75	0.872
	Tb4	0.079	66.965	75	0.893
	Tb5	0.064	68.102	75	0.908
B7	Tb1	0.116	59.195	66	0.897
	Tb3	0.082	60.494	66	0.917
	Tb4	0.062	62.432	66	0.946
	Tb5	0.050	63.715	66	0.965
B10	Tb1	0.148	48.511	56.5	0.933
	Tb3	0.104	48.893	56.5	0.940
	Tb4	0.079	49.000	56.5	0.942
	Tb5	0.064	49.995	56.5	0.961

B13 Tb1	0.116	53.027	51	0.947
Tb3	0.082	54.062	51	0.965
Tb4	0.062	54.488	51	0.973
Tb5	0.050	55.231	51	0.986
B16 Tb1	0.116	43.718	47.5	0.920
Tb3	0.082	44.750	47.5	0.942
Tb4	0.062	45.211	47.5	0.952
Tb5	0.050	46.110	47.5	0.971

Test Liquid 15: CMC 0.6%

Density, ρ_f =1000 kg/m^3; n=0.623; k=0.292 (P.S^n); Temp=291K

Particle ID/Tube ID	d/D	vx10^2(m/s)	V∞x10^2 (m/s)	f_w=v/V∞
P1 Tb1	0.369	10.247	14.3	0.717
Tb3	0.261	10.926	14.3	0.764
Tb4	0.198	11.812	14.3	0.826
Tb5	0.159	12.825	14.3	0.897
P4 Tb1	0.369	11.226	15.8	0.710
Tb3	0.261	12.300	15.8	0.778
Tb4	0.198	13.102	15.8	0.829
Tb5	0.159	14.001	15.8	0.886
P7 Tb1	0.369	8.431	12.9	0.654
Tb3	0.261	9.722	12.9	0.754
Tb4	0.198	10.274	12.9	0.796
Tb5	0.159	11.048	12.9	0.856
P10 Tb1	0.369	8.980	13.1	0.686
Tb3	0.261	10.053	13.1	0.767
Tb4	0.198	10.892	13.1	0.831
Tb5	0.159	11.355	13.1	0.867
P13 Tb1	0.369	7.684	11.8	0.651
Tb3	0.261	8.657	11.8	0.734
Tb4	0.198	9.416	11.8	0.798
Tb5	0.159	10.145	11.8	0.860
P22 Tb1	0.246	8.291	9.8	0.846
Tb3	0.174	8.572	9.8	0.875
Tb4	0.132	8.882	9.8	0.906
Tb5	0.106	9.122	9.8	0.931
P25 Tb1	0.246	7.296	8.5	0.858
Tb3	0.174	7.676	8.5	0.903
Tb4	0.132	7.857	8.5	0.924
Tb5	0.106	8.000	8.5	0.941
P28 Tb1	0.246	6.298	7.5	0.840
Tb3	0.174	6.622	7.5	0.883
Tb4	0.132	6.784	7.5	0.905
Tb5	0.106	6.980	7.5	0.931
A1 Tb1	0.234	27.970	31.5	0.888
Tb3	0.165	28.545	31.5	0.906
Tb4	0.126	29.355	31.5	0.932
Tb5	0.101	30.122	31.5	0.956
A4 Tb1	0.234	25.535	29.5	0.866
Tb3	0.165	25.982	29.5	0.881

	Tb4	0.126	26.697	29.5	0.905
	Tb5	0.101	28.145	29.5	0.954
A19	Tb1	0.234	38.493	48.5	0.794
	Tb3	0.165	40.387	48.5	0.833
	Tb4	0.126	42.867	48.5	0.884
	Tb5	0.101	44.556	48.5	0.919
A22	Tb1	0.234	35.489	42.5	0.835
	Tb3	0.165	37.295	42.5	0.878
	Tb4	0.126	38.653	42.5	0.909
	Tb5	0.101	39.336	42.5	0.926
A25	Tb1	0.234	31.430	37	0.849
	Tb3	0.165	32.813	37	0.887
	Tb4	0.126	33.146	37	0.896
	Tb5	0.101	33.987	37	0.919
A28	Tb1	0.172	34.933	35.6	0.944
	Tb3	0.122	35.511	35.6	0.960
	Tb4	0.093	35.777	35.6	0.967
	Tb5	0.074	36.189	35.6	0.978
A31	Tb1	0.172	29.865	33	0.905
	Tb3	0.122	30.437	33	0.922
	Tb4	0.093	30.944	33	0.938
	Tb5	0.074	31.778	33	0.963
A34	Tb1	0.172	25.536	28.5	0.896
	Tb3	0.122	25.435	28.5	0.892
	Tb4	0.093	26.464	28.5	0.929
	Tb5	0.074	27.478	28.5	0.964
A7	Tb1	0.172	22.579	25	0.903
	Tb3	0.122	23.169	25	0.927
	Tb4	0.093	23.553	25	0.942
	Tb5	0.074	23.989	25	0.960
A10	Tb1	0.172	18.567	21.6	0.860
	Tb3	0.122	19.141	21.6	0.886
	Tb4	0.093	19.766	21.6	0.915
	Tb5	0.074	20.574	21.6	0.953
B1	Tb1	0.148	76.813	93	0.826
	Tb3	0.104	80.370	93	0.864
	Tb4	0.079	83.692	93	0.900
	Tb5	0.064	86.663	93	0.932
B4	Tb1	0.148	69.853	81.5	0.857
	Tb3	0.104	72.069	81.5	0.884
	Tb4	0.079	74.061	81.5	0.909
	Tb5	0.064	77.211	81.5	0.947
B7	Tb1	0.116	65.780	75	0.877
	Tb3	0.082	67.745	75	0.903
	Tb4	0.062	69.687	75	0.929
	Tb5	0.050	71.336	75	0.951
B10	Tb1	0.148	54.327	70	0.805
	Tb3	0.104	56.550	70	0.838
	Tb4	0.079	58.042	70	0.860
	Tb5	0.064	60.144	70	0.891

B16 Tb1	0.116	58.844	67.5	0.872
Tb3	0.082	59.762	67.5	0.885
Tb4	0.062	63.681	67.5	0.943
Tb5	0.050	63.215	67.5	0.937
B19 Tb1	0.116	49.944	58	0.861
Tb3	0.082	51.602	58	0.890
Tb4	0.062	53.395	58	0.921
Tb5	0.050	54.985	58	0.948

Test Liquid 16: CMC 0.5%
Density, ρ_f =1000 kg/m^3; n=0.617; k=0.261(P.S^n); Temp=292K

Particle ID/Tube ID	d/D	vx102(m/s)	V∞x102 (m/s)	fw=v/V∞
P1 Tb1	0.369	11.388	15.5	0.735
Tb3	0.261	12.844	15.5	0.829
Tb4	0.198	13.275	15.5	0.856
Tb5	0.159	13.767	15.5	0.888
P4 Tb1	0.369	14.607	19.5	0.749
Tb3	0.261	16.088	19.5	0.825
Tb4	0.198	16.942	19.5	0.869
Tb5	0.159	17.352	14.4	0.890
P7 Tb1	0.369	10.586	14.4	0.735
Tb3	0.261	11.789	14.4	0.819
Tb4	0.198	12.267	14.4	0.852
Tb5	0.159	12.790	14.4	0.888
P10 Tb1	0.369	11.139	15.2	0.733
Tb3	0.261	12.207	15.2	0.803
Tb4	0.198	12.907	15.2	0.849
Tb5	0.159	13.477	15.2	0.887
P13 Tb1	0.369	9.685	14	0.692
Tb3	0.261	10.818	14	0.773
Tb4	0.198	11.719	14	0.837
Tb5	0.159	12.125	14	0.866
P22 Tb1	0.246	11.039	13.5	0.818
Tb3	0.174	11.419	13.5	0.846
Tb4	0.132	12.000	13.5	0.889
Tb5	0.106	12.474	13.5	0.924
P25 Tb1	0.246	9.903	12	0.825
Tb3	0.174	10.103	12	0.842
Tb4	0.132	10.718	12	0.893
Tb5	0.106	11.233	12	0.936
P28 Tb1	0.246	8.467	10.2	0.830
Tb3	0.174	8.733	10.2	0.856
Tb4	0.132	9.057	10.2	0.888
Tb5	0.106	9.669	10.2	0.948
A1 Tb1	0.234	29.169	37.5	0.778
Tb3	0.165	30.699	37.5	0.819
Tb4	0.126	32.005	37.5	0.853
Tb5	0.101	33.005	37.5	0.880
A4 Tb1	0.234	30.815	35.9	0.858
Tb3	0.165	32.567	35.9	0.907

	Tb4	0.126	33.107	35.9	0.922
	Tb5	0.101	34.897	35.9	0.972
A19	Tb1	0.234	41.675	27.5	0.765
	Tb3	0.165	44.531	27.5	0.817
	Tb4	0.126	47.200	27.5	0.866
	Tb5	0.101	49.336	27.5	0.905
A22	Tb1	0.234	36.939	44	0.840
	Tb3	0.165	38.484	44	0.875
	Tb4	0.126	39.960	44	0.908
	Tb5	0.101	41.112	44	0.934
A25	Tb1	0.234	35.174	42.5	0.828
	Tb3	0.165	36.723	42.5	0.864
	Tb4	0.126	37.598	42.5	0.885
	Tb5	0.101	40.022	42.5	0.942
A28	Tb1	0.172	34.832	41	0.820
	Tb3	0.122	36.946	41	0.869
	Tb4	0.093	37.131	41	0.874
	Tb5	0.074	38.697	41	0.911
A31	Tb1	0.172	31.887	36.1	0.883
	Tb3	0.122	33.111	36.1	0.917
	Tb4	0.093	33.721	36.1	0.934
	Tb5	0.074	34.367	36.1	0.952
A34	Tb1	0.172	27.970	30	0.932
	Tb3	0.122	28.493	30	0.950
	Tb4	0.093	28.845	30	0.961
	Tb5	0.074	29.234	30	0.974
A7	Tb1	0.172	23.404	27.5	0.851
	Tb3	0.122	24.195	27.5	0.880
	Tb4	0.093	24.944	27.5	0.907
	Tb5	0.074	25.918	27.5	0.942
A10	Tb1	0.172	21.680	25.5	0.850
	Tb3	0.122	22.434	25.5	0.880
	Tb4	0.093	23.089	25.5	0.905
	Tb5	0.074	23.998	25.5	0.941
B1	Tb1	0.148	74.635	87	0.858
	Tb3	0.104	76.079	87	0.874
	Tb4	0.079	79.332	87	0.912
	Tb5	0.064	81.944	87	0.942
B4	Tb1	0.148	70.217	83	0.846
	Tb3	0.104	73.547	83	0.886
	Tb4	0.079	76.478	83	0.921
	Tb5	0.064	77.313	83	0.931
B7	Tb1	0.116	65.790	75	0.877
	Tb3	0.082	67.692	75	0.903
	Tb4	0.062	69.325	75	0.924
	Tb5	0.050	71.847	75	0.958
B10	Tb1	0.148	56.512	70.5	0.802
	Tb3	0.104	59.817	70.5	0.848
	Tb4	0.079	62.979	70.5	0.893
	Tb5	0.064	64.806	70.5	0.919

B16 Tb1	0.116	57.876	68	0.851
Tb3	0.082	59.667	68	0.877
Tb4	0.062	62.334	68	0.917
Tb5	0.050	64.315	68	0.946
B19 Tb1	0.116	50.500	62	0.815
Tb3	0.082	53.144	62	0.857
Tb4	0.062	55.000	62	0.887
Tb5	0.050	57.124	62	0.921

Test Liquid 17: CMC 0.4%
Density, ρ_f =1000 kg/m^3; n=0.669; k=0.231(P.S^n); Temp=293K

Particle ID/Tube ID	d/D	vx10^2(m/s)	V_∞x10^2 (m/s)	$f_w=v/V_\infty$
P1 Tb1	0.369	11.488	15.8	0.727
Tb3	0.261	13.406	15.8	0.849
Tb4	0.198	13.595	15.8	0.860
Tb5	0.159	13.741	15.8	0.870
P4 Tb1	0.369	14.037	19.5	0.720
Tb3	0.261	16.239	19.5	0.833
Tb4	0.198	16.578	19.5	0.850
Tb5	0.159	16.985	19.5	0.871
P7 Tb1	0.369	10.370	14.2	0.730
Tb3	0.261	11.884	14.2	0.837
Tb4	0.198	12.019	14.2	0.846
Tb5	0.159	12.579	14.2	0.886
P10 Tb1	0.369	11.000	15	0.733
Tb3	0.261	12.490	15	0.833
Tb4	0.198	12.819	15	0.855
Tb5	0.159	13.201	15	0.880
P13 Tb1	0.369	9.316	12.5	0.745
Tb3	0.261	10.139	12.5	0.811
Tb4	0.198	10.767	12.5	0.861
Tb5	0.159	11.025	12.5	0.882
P22 Tb1	0.246	10.820	12.8	0.845
Tb3	0.174	11.008	12.8	0.860
Tb4	0.132	11.484	12.8	0.897
Tb5	0.106	12.087	12.8	0.944
P25 Tb1	0.246	9.436	12	0.786
Tb3	0.174	9.702	12	0.809
Tb4	0.132	10.478	12	0.873
Tb5	0.106	10.985	12	0.915
P28 Tb1	0.246	8.282	9.7	0.854
Tb3	0.174	8.514	9.7	0.878
Tb4	0.132	8.815	9.7	0.909
Tb5	0.106	9.140	9.7	0.942
A1 Tb1	0.234	30.009	36	0.834
Tb3	0.165	31.691	36	0.880
Tb4	0.126	32.470	36	0.902
Tb5	0.101	33.975	36	0.944
A4 Tb1	0.234	27.819	33.5	0.830
Tb3	0.165	28.882	33.5	0.862

	Tb4	0.126	29.727	33.5	0.887
	Tb5	0.101	31.416	33.5	0.938
A19	Tb1	0.234	46.383	52	0.892
	Tb3	0.165	47.432	52	0.912
	Tb4	0.126	48.376	52	0.930
	Tb5	0.101	49.140	52	0.945
A22	Tb1	0.234	39.058	44.5	0.878
	Tb3	0.165	39.866	44.5	0.896
	Tb4	0.126	41.146	44.5	0.925
	Tb5	0.101	42.241	44.5	0.949
A25	Tb1	0.234	35.971	40.5	0.888
	Tb3	0.165	36.860	40.5	0.910
	Tb4	0.126	37.504	40.5	0.926
	Tb5	0.101	38.901	40.5	0.961
A28	Tb1	0.172	35.414	39.8	0.890
	Tb3	0.122	36.649	39.8	0.921
	Tb4	0.093	37.037	39.8	0.931
	Tb5	0.074	37.975	39.8	0.954
A31	Tb1	0.172	29.803	35	0.852
	Tb3	0.122	31.306	35	0.894
	Tb4	0.093	32.015	35	0.915
	Tb5	0.074	33.198	35	0.949
A34	Tb1	0.172	27.735	32	0.867
	Tb3	0.122	28.508	32	0.891
	Tb4	0.093	29.407	32	0.919
	Tb5	0.074	30.113	32	0.941
A7	Tb1	0.172	21.628	27	0.801
	Tb3	0.122	22.614	27	0.838
	Tb4	0.093	24.235	27	0.898
	Tb5	0.074	25.065	27	0.928
A10	Tb1	0.172	19.599	25.2	0.778
	Tb3	0.122	20.999	25.2	0.833
	Tb4	0.093	22.324	25.2	0.886
	Tb5	0.074	22.984	25.2	0.912
B1	Tb1	0.148	82.069	94	0.873
	Tb3	0.104	84.550	94	0.899
	Tb4	0.079	87.122	94	0.927
	Tb5	0.064	89.408	94	0.951
B4	Tb1	0.148	75.034	83	0.904
	Tb3	0.104	76.993	83	0.928
	Tb4	0.079	78.377	83	0.944
	Tb5	0.064	79.984	83	0.964
B7	Tb1	0.116	70.217	75	0.936
	Tb3	0.082	71.024	75	0.947
	Tb4	0.062	71.972	75	0.960
	Tb5	0.050	72.688	75	0.969
B10	Tb1	0.148	67.019	73	0.918
	Tb3	0.104	67.834	73	0.929
	Tb4	0.079	69.694	73	0.955
	Tb5	0.064	70.421	73	0.965

B16 Tb1	0.116	63.464	67.5	0.940
Tb3	0.082	64.790	67.5	0.960
Tb4	0.062	65.139	67.5	0.965
Tb5	0.050	66.172	67.5	0.980
B19 Tb1	0.116	57.105	62.5	0.914
Tb3	0.082	57.990	62.5	0.928
Tb4	0.062	59.602	62.5	0.954
Tb5	0.050	60.242	62.5	0.964

Test Liquid 18: Methocel 1.2%

Density, ρ_f =1000 kg/m^3; n=0.698; k=2.069(P.S^n); Temp=296K

Particle ID/Tube ID	d/D	vx10^2(m/s)	V_∞x10^2 (m/s)	$f_w=v/V_\infty$
P1 Tb1	0.369	0.530	0.98	0.541
Tb3	0.261	0.609	0.98	0.621
Tb4	0.198	0.730	0.98	0.744
Tb5	0.159	0.795	0.98	0.811
P4 Tb1	0.369	0.558	1.2	0.465
Tb3	0.261	0.706	1.2	0.588
Tb4	0.198	0.864	1.2	0.720
Tb5	0.159	0.939	1.2	0.782
P7 Tb1	0.369	0.498	0.82	0.607
Tb3	0.261	0.562	0.82	0.685
Tb4	0.198	0.644	0.82	0.785
Tb5	0.159	0.694	0.82	0.847
P10 Tb1	0.369	0.511	0.92	0.556
Tb3	0.261	0.613	0.92	0.666
Tb4	0.198	0.690	0.92	0.750
Tb5	0.159	0.757	0.92	0.823
P13 Tb1	0.369	0.413	0.8	0.516
Tb3	0.261	0.505	0.8	0.632
Tb4	0.198	0.590	0.8	0.738
Tb5	0.159	0.639	0.8	0.798
P22 Tb1	0.246	0:388	0.6	0.646
Tb3	0.174	0.437	0.6	0.728
Tb4	0.132	0.482	0.6	0.803
Tb5	0.106	0.517	0.6	0.861
P25 Tb1	0.246	0.321	0.45	0.584
Tb3	0.174	0.396	0.45	0.721
Tb4	0.132	0.423	0.45	0.769
Tb5	0.106	0.450	0.45	0.818
P28 Tb1	0.246	0.288	0.55	0.640
Tb3	0.174	0.326	0.55	0.725
Tb4	0.132	0.360	0.55	0.800
Tb5	0.106	0.384	0.55	0.854
P31 Tb1	0.246	0.235	0.33	0.713
Tb3	0.174	0.271	0.33	0.822
Tb4	0.132	0.282	0.33	0.854
Tb5	0.106	0.286	0.33	0.866
A1 Tb1	0.234	2.604	3.9	0.668
Tb3	0.165	2.897	3.9	0.743

	Tb4	0.126	3.209	3.9	0.823
	Tb5	0.101	3.318	3.9	0.851
A4	Tb1	0.234	2.310	3.4	0.745
	Tb3	0.165	2.569	3.4	0.829
	Tb4	0.126	2.715	3.4	0.876
	Tb5	0.101	2.917	3.4	0.941
A19	Tb1	0.234	4.781	6.6	0.714
	Tb3	0.165	5.047	6.6	0.753
	Tb4	0.126	5.426	6.6	0.810
	Tb5	0.101	5.950	6.6	0.888
A22	Tb1	0.234	3.658	5	0.732
	Tb3	0.165	4.060	5	0.812
	Tb4	0.126	4.532	5	0.906
	Tb5	0.101	4.756	5	0.951
A25	Tb1	0.234	3.296	4.8	0.687
	Tb3	0.165	3.799	4.8	0.791
	Tb4	0.126	3.950	4.8	0.823
	Tb5	0.101	4.237	4.8	0.883
A28	Tb1	0.172	2.296	3.5	0.656
	Tb3	0.122	2.545	3.5	0.727
	Tb4	0.093	2.819	3.5	0.805
	Tb5	0.074	2.961	3.5	0.846
A31	Tb1	0.172	2.114	3.1	0.682
	Tb3	0.122	2.376	3.1	0.766
	Tb4	0.093	2.563	3.1	0.827
	Tb5	0.074	2.646	3.1	0.854
A34	Tb1	0.172	1.809	2.6	0.696
	Tb3	0.122	2.087	2.6	0.803
	Tb4	0.093	2.145	2.6	0.825
	Tb5	0.074	2.275	2.6	0.875
A7	Tb1	0.172	1.596	2.4	0.665
	Tb3	0.122	1.790	2.4	0.746
	Tb4	0.093	1.939	2.4	0.808
	Tb5	0.074	2.106	2.4	0.878
A10	Tb1	0.172	1.317	1.7	0.775
	Tb3	0.122	1.360	1.7	0.800
	Tb4	0.093	1.456	1.7	0.857
	Tb5	0.074	1.567	1.7	0.922

Test Liquid 19: Methocel 1.0%

Density, ρ_f =1000 kg/m^3; n=0.720; k=1.074(P.S^n); Temp=296K

Particle ID/Tube ID		d/D	vx10^2(m/s)	V_∞x10^2 (m/s)	f_w=v/V_∞
P1	Tb1	0.369	0.887	2.8	0.493
	Tb3	0.261	1.088	2.8	0.604
	Tb4	0.198	1.276	2.8	0.709
	Tb5	0.159	1.441	2.8	0.801
P4	Tb1	0.369	0.954	3.6	0.424
	Tb3	0.261	1.279	3.6	0.569
	Tb4	0.198	1.553	3.6	0.690
	Tb5	0.159	1.690	3.6	0.751

P7	Tb1	0.369	0.788	2.52	0.518
	Tb3	0.261	0.961	2.52	0.632
	Tb4	0.198	1.121	2.52	0.737
	Tb5	0.159	1.221	2.52	0.804
P10	Tb1	0.369	0.820	2.22	0.483
	Tb3	0.261	1.045	2.22	0.615
	Tb4	0.198	1.218	2.22	0.716
	Tb5	0.159	1.326	2.22	0.780
P13	Tb1	0.369	0.724	1.48	0.489
	Tb3	0.261	0.873	1.48	0.590
	Tb4	0.198	1.106	1.48	0.747
	Tb5	0.159	1.134	1.48	0.766
P22	Tb1	0.246	0.659	1.85	0.599
	Tb3	0.174	0.763	1.85	0.693
	Tb4	0.132	0.864	1.85	0.786
	Tb5	0.106	0.925	1.85	0.840
P25	Tb1	0.246	0.573	1.2	0.573
	Tb3	0.174	0.667	1.2	0.667
	Tb4	0.132	0.782	1.2	0.782
	Tb5	0.106	0.810	1.2	0.810
P28	Tb1	0.246	0.497	0.85	0.663
	Tb3	0.174	0.574	0.85	0.766
	Tb4	0.132	0.617	0.85	0.822
	Tb5	0.106	0.634	0.85	0.845
A1	Tb1	0.246	0.399	0.6	0.665
	Tb3	0.174	0.468	0.6	0.780
	Tb4	0.132	0.480	0.6	0.800
	Tb5	0.106	0.513	0.6	0.856
A4	Tb1	0.148	11.063	42.5	0.738
	Tb3	0.104	11.859	42.5	0.791
	Tb4	0.079	12.859	42.5	0.857
	Tb5	0.064	13.444	42.5	0.896
A19	Tb1	0.148	9.427	37	0.673
	Tb3	0.104	10.503	37	0.750
	Tb4	0.079	11.444	37	0.817
	Tb5	0.064	12.193	37	0.871
A22	Tb1	0.116	6.441	32.7	0.758
	Tb3	0.082	6.638	32.7	0.781
	Tb4	0.062	7.224	32.7	0.850
	Tb5	0.050	7.824	32.7	0.921
A25	Tb1	0.148	6.384	29.5	0.709
	Tb3	0.104	6.765	29.5	0.752
	Tb4	0.079	7.535	29.5	0.837
	Tb5	0.064	8.098	29.5	0.900
A28	Tb1	0.116	5.804	20.22	0.726
	Tb3	0.082	6.194	20.22	0.774
	Tb4	0.062	6.721	20.22	0.840
	Tb5	0.050	7.061	20.22	0.883
A31	Tb1	0.116	4.263	19.5	0.710
	Tb3	0.082	4.494	19.5	0.749

Tb4	0.062	5.139	19.5	0.857
Tb5	0.050	5.251	19.5	0.875

Test Liquid 20: Methocel 0.75%
Density, ρ_f =1000 kg/m^3; n=0.663; k=1.003(P.S^n); Temp=288K

Particle ID/Tube ID	d/D	vx10^2(m/s)	V_∞x10^2 (m/s)	f_w=v/V_∞
P1 Tb1	0.369	2.733	4.2	0.651
Tb3	0.261	3.072	4.2	0.731
Tb4	0.198	3.444	4.2	0.820
Tb5	0.159	3.600	4.2	0.857
P4 Tb1	0.369	3.154	5.3	0.595
Tb3	0.261	3.691	5.3	0.696
Tb4	0.198	4.113	5.3	0.776
Tb5	0.159	4.407	5.3	0.832
P7 Tb1	0.369	2.241	3.7	0.606
Tb3	0.261	2.563	3.7	0.693
Tb4	0.198	2.848	3.7	0.770
Tb5	0.159	3.104	3.7	0.839
P10 Tb1	0.369	2.458	4.16	0.591
Tb3	0.261	2.836	4.16	0.682
Tb4	0.198	3.264	4.16	0.785
Tb5	0.159	3.408	4.16	0.819
P22 Tb1	0.246	1.912	2.8	0.683
Tb3	0.174	2.131	2.8	0.761
Tb4	0.132	2.256	2.8	0.806
Tb5	0.106	2.456	2.8	0.877
P25 Tb1	0.246	1.701	2.75	0.618
Tb3	0.174	1.936	2.75	0.704
Tb4	0.132	2.024	2.75	0.736
Tb5	0.106	2.180	2.75	0.793
P28 Tb1	0.246	1.508	2	0.754
Tb3	0.174	1.651	2	0.825
Tb4	0.132	1.680	2	0.840
Tb5	0.106	1.849	2	0.924
A1 Tb1	0.234	11.169	15	0.745
Tb3	0.165	12.582	15	0.839
Tb4	0.126	12.657	15	0.844
Tb5	0.101	13.637	15	0.909
A4 Tb1	0.234	9.646	13	0.742
Tb3	0.165	10.473	13	0.806
Tb4	0.126	10.931	13	0.841
Tb5	0.101	11.943	13	0.919
A19 Tb1	0.234	16.962	23	1.804
Tb3	0.165	17.913	23	1.906
Tb4	0.126	19.351	23	2.059
Tb5	0.101	20.658	23	2.198
A22 Tb1	0.234	15.162	20	1.805
Tb3	0.165	15.624	20	1.860
Tb4	0.126	17.157	20	2.043
Tb5	0.101	18.031	20	2.147

A25	Tb1	0.234	13.501	17.2	0.785
	Tb3	0.165	14.197	17.2	0.825
	Tb4	0.126	14.870	17.2	0.865
	Tb5	0.101	15.962	17.2	0.928
A28	Tb1	0.172	9.651	12.2	0.791
	Tb3	0.122	9.946	12.2	0.815
	Tb4	0.093	10.852	12.2	0.890
	Tb5	0.074	11.223	12.2	0.920
A31	Tb1	0.172	8.801	11.6	0.759
	Tb3	0.122	9.226	11.6	0.795
	Tb4	0.093	9.957	11.6	0.858
	Tb5	0.074	10.545	11.6	0.909
A34	Tb1	0.172	8.360	10.6	0.789
	Tb3	0.122	9.024	10.6	0.851
	Tb4	0.093	9.376	10.6	0.885
	Tb5	0.074	9.648	10.6	0.910
A7	Tb1	0.172	6.736	9.4	0.717
	Tb3	0.122	7.318	9.4	0.779
	Tb4	0.093	7.845	9.4	0.835
	Tb5	0.074	8.366	9.4	0.890
A10	Tb1	0.172	5.900	8.4	0.702
	Tb3	0.122	6.558	8.4	0.781
	Tb4	0.093	7.207	8.4	0.858
	Tb5	0.074	7.350	8.4	0.875
B1	Tb1	0.148	36.732	49.5	0.742
	Tb3	0.104	39.923	49.5	0.807
	Tb4	0.079	42.374	49.5	0.856
	Tb5	0.064	44.111	49.5	0.891
B4	Tb1	0.148	31.129	44	0.707
	Tb3	0.104	33.591	44	0.763
	Tb4	0.079	36.033	44	0.819
	Tb5	0.064	38.363	44	0.872
B7	Tb1	0.116	25.866	34	0.761
	Tb3	0.082	27.180	34	0.799
	Tb4	0.062	29.355	34	0.863
	Tb5	0.050	31.065	34	0.914
B10	Tb1	0.148	26.528	36	0.737
	Tb3	0.104	28.180	36	0.783
	Tb4	0.079	30.022	36	0.834
	Tb5	0.064	32.303	36	0.897
B16	Tb1	0.116	23.909	33	0.725
	Tb3	0.082	25.672	33	0.778
	Tb4	0.062	27.802	33	0.842
	Tb5	0.050	29.173	33	0.884
B19	Tb1	0.116	18.714	25	0.749
	Tb3	0.082	19.475	25	0.779
	Tb4	0.062	21.483	25	0.859
	Tb5	0.050	22.532	25	0.901

Test Liquid 20: Methocel 0.65%

Density, ρ_f =1000 kg/m^3; n=0.689; k=0.662(P.S^n); Temp=289K

Particle ID/Tube ID		d/D	vx10^2(m/s)	V_∞x10^2 (m/s)	f_w=v/V_∞
P1	Tb1	0.369	4.014	6.6	0.608
	Tb3	0.261	4.571	6.6	0.693
	Tb4	0.198	5.237	6.6	0.793
	Tb5	0.159	5.507	6.6	0.834
P4	Tb1	0.369	4.800	7.75	0.619
	Tb3	0.261	5.540	7.75	0.715
	Tb4	0.198	6.175	7.75	0.797
	Tb5	0.159	6.500	7.75	0.839
P7	Tb1	0.369	3.411	5.75	0.593
	Tb3	0.261	4.020	5.75	0.699
	Tb4	0.198	4.474	5.75	0.778
	Tb5	0.159	4.777	5.75	0.831
P10	Tb1	0.369	3.714	6	0.619
	Tb3	0.261	4.382	6	0.730
	Tb4	0.198	4.785	6	0.797
	Tb5	0.159	5.068	6	0.845
P13	Tb1	0.369	3.019	5.1	0.592
	Tb3	0.261	3.471	5.1	0.681
	Tb4	0.198	3.876	5.1	0.760
	Tb5	0.159	4.288	5.1	0.841
P22	Tb1	0.246	3.043	4.5	0.676
	Tb3	0.174	3.315	4.5	0.737
	Tb4	0.132	3.572	4.5	0.794
	Tb5	0.106	3.845	4.5	0.855
P25	Tb1	0.246	2.591	3.75	0.691
	Tb3	0.174	2.928	3.75	0.781
	Tb4	0.132	3.123	3.75	0.833
	Tb5	0.106	3.240	3.75	0.864
P28	Tb1	0.246	2.284	3	0.761
	Tb3	0.174	2.493	3	0.831
	Tb4	0.132	2.602	3	0.867
	Tb5	0.106	2.740	3	0.913
A1	Tb1	0.234	16.646	19.8	0.841
	Tb3	0.165	17.217	19.8	0.870
	Tb4	0.126	17.994	19.8	0.909
	Tb5	0.101	18.407	19.8	0.930
A4	Tb1	0.234	14.130	17.5	0.807
	Tb3	0.165	15.066	17.5	0.861
	Tb4	0.126	15.559	17.5	0.889
	Tb5	0.101	16.115	17.5	0.921
A19	Tb1	0.234	25.992	12.2	2.130
	Tb3	0.165	27.354	12.2	2.242
	Tb4	0.126	28.397	12.2	2.328
	Tb5	0.101	29.130	12.2	2.388
A22	Tb1	0.234	22.613	28	0.808
	Tb3	0.165	23.724	28	0.847
	Tb4	0.126	25.194	28	0.900
	Tb5	0.101	25.650	28	0.916

A25	Tb1	0.234	18.966	23.2	0.818
	Tb3	0.165	20.212	23.2	0.871
	Tb4	0.126	21.129	23.2	0.911
	Tb5	0.101	21.308	23.2	0.918
A28	Tb1	0.172	16.406	19	0.863
	Tb3	0.122	17.076	19	0.899
	Tb4	0.093	17.542	19	0.923
	Tb5	0.074	17.876	19	0.941
A31	Tb1	0.172	14.668	17	0.863
	Tb3	0.122	14.852	17	0.874
	Tb4	0.093	15.773	17	0.928
	Tb5	0.074	15.859	17	0.933
A34	Tb1	0.172	12.768	14.8	0.863
	Tb3	0.122	13.062	14.8	0.883
	Tb4	0.093	13.611	14.8	0.920
	Tb5	0.074	13.954	14.8	0.943
A7	Tb1	0.172	10.440	12.2	0.856
	Tb3	0.122	10.601	12.2	0.869
	Tb4	0.093	11.205	12.2	0.918
	Tb5	0.074	11.462	12.2	0.940
A10	Tb1	0.172	9.245	11	0.840
	Tb3	0.122	9.491	11	0.863
	Tb4	0.093	9.970	11	0.906
	Tb5	0.074	10.363	11	0.942
B1	Tb1	0.148	61.182	68	0.900
	Tb3	0.104	62.548	68	0.920
	Tb4	0.079	63.891	68	0.940
	Tb5	0.064	65.690	68	0.966
B4	Tb1	0.148	52.474	58.2	0.902
	Tb3	0.104	53.859	58.2	0.925
	Tb4	0.079	54.850	58.2	0.942
	Tb5	0.064	56.140	58.2	0.965
B7	Tb1	0.116	41.409	46.2	0.896
	Tb3	0.082	42.654	46.2	0.923
	Tb4	0.062	43.448	46.2	0.940
	Tb5	0.050	44.322	46.2	0.959
B10	Tb1	0.148	38.100	41	0.929
	Tb3	0.104	38.946	41	0.950
	Tb4	0.079	39.489	41	0.963
	Tb5	0.064	39.521	41	0.964
B16	Tb1	0.116	37.412	40	0.935
	Tb3	0.082	37.823	40	0.946
	Tb4	0.062	38.445	40	0.961
	Tb5	0.050	39.066	40	0.977
B19	Tb1	0.116	32.346	33.5	0.966
	Tb3	0.082	32.564	33.5	0.972
	Tb4	0.062	32.749	33.5	0.978
	Tb5	0.050	32.963	33.5	0.984

Test Liquid 21: Methocel 0.5%

Density, ρ_f =1000 kg/m^3; n=0.690; k=0.383(P.S^n); Temp=289K

Particle ID/Tube ID		d/D	vx102(m/s)	V∞x102 (m/s)	fw=v/V∞
P1	Tb1	0.369	9.459	14	0.676
	Tb3	0.261	10.802	14	0.772
	Tb4	0.198	11.303	14	0.807
	Tb5	0.159	12.240	14	0.874
P4	Tb1	0.369	11.473	16.3	0.704
	Tb3	0.261	12.985	16.3	0.797
	Tb4	0.198	13.336	16.3	0.818
	Tb5	0.159	14.443	16.3	0.886
P7	Tb1	0.369	8.007	12.8	0.626
	Tb3	0.261	9.225	12.8	0.721
	Tb4	0.198	9.932	12.8	0.776
	Tb5	0.159	10.876	12.8	0.850
P10	Tb1	0.369	8.846	13.2	0.670
	Tb3	0.261	10.550	13.2	0.799
	Tb4	0.198	10.815	13.2	0.819
	Tb5	0.159	11.342	13.2	0.859
P13	Tb1	0.369	7.421	11	0.675
	Tb3	0.261	8.353	11	0.759
	Tb4	0.198	8.950	11	0.814
	Tb5	0.159	9.514	11	0.865
P22	Tb1	0.246	7.550	10.2	0.740
	Tb3	0.174	8.118	10.2	0.796
	Tb4	0.132	8.749	10.2	0.858
	Tb5	0.106	9.033	10.2	0.886
P25	Tb1	0.246	7.204	7	0.800
	Tb3	0.174	7.918	7	0.880
	Tb4	0.132	8.029	7	0.892
	Tb5	0.106	8.127	7	0.903
P28	Tb1	0.246	5.861	7.8	0.751
	Tb3	0.174	6.362	7.8	0.816
	Tb4	0.132	6.668	7.8	0.855
	Tb5	0.106	6.965	7.8	0.893
A1	Tb1	0.234	26.102	32	0.816
	Tb3	0.165	27.709	32	0.866
	Tb4	0.126	28.732	32	0.898
	Tb5	0.101	29.810	32	0.932
A4	Tb1	0.234	22.830	29.5	0.749
	Tb3	0.165	25.625	29.5	0.840
	Tb4	0.126	26.270	29.5	0.861
	Tb5	0.101	27.169	29.5	0.891
A19	Tb1	0.234	37.919	52.6	0.751
	Tb3	0.165	41.556	52.6	0.823
	Tb4	0.126	43.829	52.6	0.868
	Tb5	0.101	45.038	52.6	0.892
A22	Tb1	0.234	33.191	42	0.790
	Tb3	0.165	34.910	42	0.831
	Tb4	0.126	36.881	42	0.878
	Tb5	0.101	38.499	42	0.917

A25	Tb1	0.234	30.049	36.7	0.791
	Tb3	0.165	32.446	36.7	0.854
	Tb4	0.126	33.293	36.7	0.876
	Tb5	0.101	34.978	36.7	0.920
A28	Tb1	0.172	29.189	35	0.834
	Tb3	0.122	30.161	35	0.862
	Tb4	0.093	31.782	35	0.908
	Tb5	0.074	32.669	35	0.933
A31	Tb1	0.172	26.037	31.5	0.840
	Tb3	0.122	26.672	31.5	0.860
	Tb4	0.093	28.294	31.5	0.913
	Tb5	0.074	28.760	31.5	0.928
A34	Tb1	0.172	22.277	28.5	0.796
	Tb3	0.122	24.307	28.5	0.868
	Tb4	0.093	24.707	28.5	0.882
	Tb5	0.074	25.352	28.5	0.905
A7	Tb1	0.172	18.875	24	0.786
	Tb3	0.122	20.204	24	0.842
	Tb4	0.093	20.627	24	0.859
	Tb5	0.074	22.100	24	0.921
A10	Tb1	0.172	16.425	22.5	0.764
	Tb3	0.122	17.673	22.5	0.822
	Tb4	0.093	18.868	22.5	0.878
	Tb5	0.074	19.313	22.5	0.898
B1	Tb1	0.148	67.747	83	0.816
	Tb3	0.104	70.197	83	0.846
	Tb4	0.079	74.501	83	0.898
	Tb5	0.064	78.929	83	0.951
B4	Tb1	0.148	56.702	73	0.777
	Tb3	0.104	60.204	73	0.825
	Tb4	0.079	62.775	73	0.860
	Tb5	0.064	66.841	73	0.916
B7	Tb1	0.116	48.284	60	0.805
	Tb3	0.082	49.822	60	0.830
	Tb4	0.062	52.632	60	0.877
	Tb5	0.050	55.586	60	0.926
B10	Tb1	0.148	47.742	58	0.796
	Tb3	0.104	50.187	58	0.836
	Tb4	0.079	53.285	58	0.888
	Tb5	0.064	56.953	58	0.949
B16	Tb1	0.116	45.011	55	0.818
	Tb3	0.082	46.722	55	0.849
	Tb4	0.062	49.758	55	0.905
	Tb5	0.050	51.210	55	0.931
B19	Tb1	0.116	36.376	45	0.808
	Tb3	0.082	38.868	45	0.864
	Tb4	0.062	40.871	45	0.908
	Tb5	0.050	42.790	45	0.951

APPENDIX C

Test Liquid 12: CMC 1.5%
Density, ρ_f =1000 kg/m^3; Temp=300K

Shear Stress (Pa)	Shear Rate (1/s)
7.68E+00	1.43E+00
1.26E+01	3.14E+00
1.76E+01	6.46E+00
2.27E+01	1.17E+01
3.25E+01	2.97E+01
4.75E+01	9.68E+01
5.26E+01	1.36E+02
5.75E+01	1.83E+02
6.25E+01	2.40E+02
6.76E+01	3.06E+02
7.25E+01	3.73E+02
7.75E+01	4.49E+02
9.25E+01	7.20E+02
9.76E+01	8.41E+02
1.03E+02	9.60E+02

Test Liquid 13: CMC 1.3%
Density, ρ_f =1000 kg/m^3; Temp=291K

Shear Stress (Pa)	Shear Rate (1/s)
2.67E+00	1.43E+00
7.64E+00	1.16E+01
1.25E+01	2.68E+01
1.75E+01	5.09E+01
2.25E+01	8.68E+01
2.75E+01	1.18E+02

Test Liquid 14: CMC 0.75%
Density, ρ_f =1000 kg/m^3; Temp=291K

Shear Stress (Pa)	Shear Rate (1/s)
0.85	1.43E+00
2.64E+00	1.62E+01
7.57E+00	8.24E+01
1.27E+01	2.06E+02
1.76E+01	3.74E+02
2.26E+01	5.91E+02
2.77E+01	8.40E+02

Test Liquid 15: CMC 0.6%
Density, ρ_f =1000 kg/m^3; Temp=291K

Shear Stress (Pa)	Shear Rate (1/s)
0.6	1.43E+00
2.68E+00	3.54E+01
7.54E+00	1.82E+02
1.25E+01	4.18E+02
1.76E+01	7.27E+02

Test Liquid 16: CMC 0.5%
Density, ρ_f =1000 kg/m^3; Temp=292K

Shear Stress (Pa)	Shear Rate (1/s)
0.35	1.43E+00
2.64E+00	4.25E+01
7.58E+00	2.37E+02
1.27E+01	5.50E+02
1.75E+01	9.04E+02

Test Liquid 17: CMC 0.4%
Density, ρ_f =1000 kg/m^3; Temp=293K

Shear Stress (Pa)	Shear Rate (1/s)
2.64E+00	3.78E+01
7.56E+00	1.87E+02
1.27E+01	4.03E+02

Test Liquid 18: Methocel 1.2%
Density, ρ_f =1000 kg/m^3; Temp=296K

Shear Stress (Pa)	Shear Rate (1/s)

2.62E+00	1.71E+00
7.56E+00	5.90E+00
1.26E+01	1.18E+01
1.76E+01	1.91E+01
2.25E+01	2.80E+01
2.76E+01	3.90E+01
3.26E+01	5.14E+01
3.75E+01	6.60E+01
4.25E+01	8.26E+01
4.75E+01	1.02E+02

Test Liquid 19: Methocel 1.0%
Density, ρ_f =1000 kg/m^3; Temp=296K

Shear Stress (Pa)	Shear Rate (1/s)
1.64E+00	1.71E+00
2.59E+00	3.75E+00
7.60E+00	1.40E+01
1.26E+01	2.82E+01
1.77E+01	4.66E+01
2.26E+01	6.80E+01
2.75E+01	9.37E+01
3.27E+01	1.26E+02

Test Liquid 20: Methocel 0.75%
Density, ρ_f =1000 kg/m^3; Temp=288K

Shear Stress (Pa)	Shear Rate (1/s)
1.24E+00	1.71E+00
2.63E+00	5.02E+00
7.65E+00	1.95E+01
1.25E+01	3.99E+01
1.75E+01	6.72E+01
2.27E+01	1.02E+02
2.75E+01	1.43E+02
3.25E+01	1.92E+02
3.77E+01	2.51E+02
4.26E+01	3.15E+02

4.76E+01	3.91E+02
5.26E+01	4.75E+02

Test Liquid 20: Methocel 0.65%
Density, ρ_f =1000 kg/m^3; Temp=289K

Shear Stress '(Pa)	Shear Rate '(1/s)
1.02E+00	1.71E+00
2.69E+00	8.25E+00
7.59E+00	3.20E+01
1.25E+01	6.67E+01
1.76E+01	1.14E+02
2.25E+01	1.71E+02
2.75E+01	2.41E+02

Test Liquid 21: Methocel 0.5%
Density=1000kg/m^3; Temp=289K

Shear Stress (Pa)	Shear Rate (1/s)
6.50E-01	1.71E+00
2.67E+00	1.70E+01
7.56E+00	6.91E+01
1.26E+01	1.45E+02
1.76E+01	2.44E+02
2.25E+01	3.58E+02
2.75E+01	4.83E+02